ASSESSMENT OF MANAGEMENT OF AGRICULTURAL DRAINAGE WATER ON VECTOR MOSQUITO ABUNDANCE in the WESTERN SAN JOAQUIN VALLEY OF CALIFORNIA

Prepared for the

San Joaquin Valley Drainage Program
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The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public health, (2) surface- and ground-water resources, (3) agricultural productivity, and (4) fish and wildlife resources.

Inquiries concerning the San Joaquin Valley Drainage Program may be directed to:

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2800 Cottage Way, Room W-2143
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This report presents the results of studies conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute endorsement or recommendation.

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EXECUTIVE SUMMARY

The lack of adequate drainage is a serious problem for irrigated agriculture in the western and southern San Joaquin Valley of California which is complicated by the fact that shallow ground water contains high concentrations of salts requiring drainage of shallow ground water for agricultural production.

Shallow ponds are currently being used to evaporate subsurface drainage water in 27 locations with ponds covering approximately 7,350 acres. Evaporation ponds and pond associated sources such as storage ponds and delivery canals could serve as sources of mosquito vectors of arboviruses which cause clinical disease in humans. The exploitation of evaporation ponds and related sources by vector mosquitoes could increase mosquito abundance and increase the risk of mosquito transmitted diseases in the human and animal populations.

Western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) are the 2 most important mosquito-borne diseases in the western San Joaquin Valley. These diseases are caused by viruses which are normally transmitted between wild birds and vector mosquitoes of which Cx. tarsalis is recognized as the principle vector. A large outbreak occurred in the San Joaquin Valley in 1952 with estimated over 1000 cases with 375 confirmed cases of WEE, more recently 27 clinical cases of SLE occurred in 1989. This number of cases is significant in that the ratio of apparent to inapparent infections with SLE virus is ranges from 1/200 to 1/1000 indicating that several thousand

people were infected and at risk of encephalitis. An increase in vector mosquito populations has been shown to increase the risk of SLE and WEE infection in the human population.

Evaporation Ponds as Sources of Culex tarsalis

Evaporation ponds were assessed as mosquito sources by inspecting ponds for evidence of mosquito larvae, interviewing mosquito abatement district (MAD) personnel to determine whether ponds have a positive history as larval sources and by testing the ability of *Cx. tarsalis* larvae to survive in water samples from evaporation ponds. Water quality analysis was conducted on the samples in which larval survivorship was tested.

Six ponds were inspected for indirect evidence of mosquito breeding during December 1989. Five ponds showed no evidence of mosquito breeding but the remaining pond contained conditions associated with *Cx. tarsalis* breeding sites including certain aquatic insects and mosquito fish, *Gambusia affinis*, suggesting that this pond could be a source of *Cx. tarsalis*. These observations were confirmed by mosquito abatement personnel.

Culex tarsalis larvae successfully hatched and developed into pupae in water collected from 2 ponds suggesting that these ponds could support larval development. The water samples in which *Cx. tarsalis* successfully survived had lower electrical conductivity readings and lower concentrations of Mg, Na, and SO_4 ions than water samples where no hatching occurred. These findings suggest that high salinity prevent *Cx. tarsalis* from utilizing certain evaporation ponds as larval sources.

Since not all ponds were tested and salinity is likely to fluctuate depending on inflow and evaporation rates additional sampling of other ponds on a year round basis would be required to assess the potential of other evaporation ponds as larval sources.

Yearly and Seasonal Abundance Patterns

The objectives of this study were to describe the seasonal abundance patterns of the 4 principle species of mosquitoes in the western San Joaquin Valley and determine whether seasonal abundance patterns and or mean yearly abundance had undergone detectable changes in the past few years. Changes in seasonal phenology may be the result of changes in agricultural water management in response to increasing drainage related problems.

Abundance patterns for *Cx. tarsalis*, *Cx. quinquefasciatus*, *Ae. melanimon* and *Ae. nigromaculis* by compiling and examining New Jersey light trap records from approximately 1980-1989 for 11 locations provided by the Merced County, Fresno-Westside and Kings Mosquito Abatement Districts. Year to year changes in abundance were made by comparing the mean numbers of females collected per week for each year. Within season abundance patterns were examined by plotting means numbers of females collected per week of each species collected in individual traps.

Numbers of all 4 species declined sharply in recent years in rural western Fresno and Kings Counties while remaining relatively unchanged in other locations. In addition, peak abundance of *Cx. tarsalis* and *Cx. quinquefasciatus* shifted from

summer to the fall. The decline in summer populations may reflect a reduction in available larval habitat.

Reductions in numbers of larval sources may be the result of changes in irrigation practices in response to drainage-related problems or other factors such as reduced water availability due to 3 years of subnormal snowpack in key watershed areas and local rainfall in California may also be responsible. A more comprehensive study is required to determine the cause of changes in mosquito population dynamics.

Recommendations

1) Involve the Mosquito Abatement Districts in San Joaquin Valley in the process of planning and implementing solutions to drainage related problems in the San Joaquin Valley.

2) Inspect additional evaporation ponds and monitor water quality in evaporation ponds year round to identify ponds in which conditions permitting *Cx. tarsalis* development exist (e.g. low salinity).

3) Determine the extent to which canals and ponds used to store drainage water are used as larval habitat by mosquitoes.

4) Assess in laboratory and in-situ the tolerance of other species of mosquitoes present in the western San Joaquin Valley to high salinity in order to determine to what extent these species could exploit evaporation ponds as larval breeding sites.

5) Continue monitoring of adult mosquito populations using New Jersey light traps and use dry ice baited portable traps to assess abundance near evaporation pond.

6) Assess the impact of changes in irrigation practices on mosquito abundance by surveying areas with different methods of irrigation for the number and size of actual and potential larval habitats.

7) Monitor for arbovirus activity to determine the impact of changing patterns of mosquito abundance on virus activity in the western San Joaquin Valley. Activities would include testing mosquito pools for evidence of vector infection rates and establishing standard sentinel chicken flocks in the area to measure virus transmission rates.

8) Examine other vector-disease systems which may be effected by the San Joaquin Valley Drainage Program. Other vector-disease systems that require further consideration include mosquito-canine heartworm and _Culicoides_ gnat-bluetongue in sheep and cattle. The latter may be more important since _Culicoides_ gnats are quite tolerant of breeding sites containing extremes in chemical parameters.

CHAPTER 1. INTRODUCTION AND OVERVIEW

Drainage Problems In the San Joaquin Valley

The lack of adequate drainage is a serious problem for irrigated agriculture in the western and southern San Joaquin Valley of California. This problem is complicated by the fact that shallow ground water found in much of the western half of the valley contains high concentrations of salts. Drainage of saline shallow ground water is required for agricultural production in low lying areas (SJVDP 1989A).

A master drainage canal was constructed to export agricultural drainage water into the Sacramento-San Joaquin Delta but the canal was not completed. Instead drainage water was held in the Kesterson Reservoir near Gustine in Merced County. The discovery of selenium induced deaths and deformities in birds at the Kesterson Reservoir (Tanji et al. 1986) led to the recognition that the public health concerns should be addressed in proposed solutions to drainage related problems in the San Joaquin Valley (SJVDP 1989A).

Evaporation Ponds

A number of options for managing drainage related problems have been proposed for solving agricultural drainage and drainage-related problems in the San Joaquin Valley (SJVDP 1989A). Shallow ponds are currently being used to evaporate saline subsurface drainage water and are considered an important alternative for the future. There were approximately 27 evaporation ponds in the San Joaquin Valley as of July 1988

covering approximately 7,350 acres (Wescott et al. 1988). The majority of these ponds were placed in operation between 1980-1985 though one pond was placed in operation in 1972 (SJVDP 1989B).

Three types of evaporation ponds are currently being used to evaporate agricultural drainage water: 1) in-series, 2) unicellular wet and 3) unicellular dry (Wescott et al. 1988). In-series ponds are divided into cells with water pumped from cell to cell as salinity increases. Salinity can differ greatly between cells.

Unicellular wet ponds contain only 1 cell which contains water permanently. The salinity of these ponds depends on the salinity of inflow and water in the pond, the rate of inflow and the rate of evaporation.

Unicellular dry ponds contain only 1 cell which is dry when not in use. Salinity varies based on the salinity of inflow water, the volume of salt present in the pond and the rate of evaporation. The salinity of ponds will increase with the number of years of use.

Evaporation ponds are of public health importance since selenium, arsenic and other minerals in subsurface drainage water can be concentrated to toxic levels in evaporation ponds. Evaporation ponds and pond associated sources such as storage ponds and delivery canals could serve as sources of mosquito vectors of viruses known to cause clinical disease in humans and domestic animals.

Utilization of evaporation ponds by vector mosquitoes may alter the abundance and distribution of mosquito populations possibly resulting in increased frequency of mosquito-human contact and increased risk of mosquito-borne diseases to humans.

Mosquito-Borne Viruses in the San Joaquin Valley

Several important mosquito transmitted viruses which cause clinical illness in humans occur in the San Joaquin Valley. Of these western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE) viruses are the 2 most important. A large outbreak of WEE and SLE occurred in Kern County in 1952 (Reeves and Hammon 1962). Of 813 cases of encephalitis reported in humans, 375 were caused by WEE and a lesser number by SLE virus. An outbreak of SLE occurred in the San Joaquin Valley in 1989 with 27 cases reported from Kern, Kings and Tulare Counties (W.C. Reeves personal communication). This number of clinical cases is highly significant in that the ratio of apparent to inapparent infections with SLE virus is 1 to several hundred (Tsai and Mitchell 1989) indicating that several thousand individuals probably became infected with the virus and were at risk of developing encephalitis or dying from the infection. The 1989 outbreak indicates that the human population in the San Joaquin Valley is still at risk from these viruses.

Both viruses produce central nervous system infection in man with symptoms ranging from inapparent to death from encephalitis. The ratio of inapparent to apparent infection is age dependent with young children more likely to develop serious illness with

WEE and older adults more likely to develop serious illness with SLE (Reisen and Monath 1989, Tsai and Mitchell 1989). Humans serve as dead end hosts for the viruses since humans do not produce a high enough viremia of sufficient duration to infect vector mosquitoes (Reeves and Hammon 1962).

No practical commercial vaccine is available for human use and vector control is the only practical approach to confronting these diseases.

The summer transmission cycle for these viruses is similar with Culex tarsalis recognized as the principle vector (Reeves and Hammon 1962). Wild birds are the principle vertebrate hosts with small mammals also involved in the transmission of WEE. Aedes melanimon is recognized as an important vector of WEE (Hardy 1987) and Culex quinquefasciatus is an important vector of SLE virus (Tsai and Mitchell 1989).

Factors which increase vector mosquito populations increase the risk of mosquito transmitted disease in the human population. An important characteristic of the dynamics of WEE and SLE viruses is that virus amplification in the wild bird population is closely associated with increased abundance of vector mosquito populations (Reeves and Hammon 1962, Tsai and Mitchell 1989). Increased mosquito abundance increases the probability of host/vector contact. Increased mosquito population levels also increase the frequency of mosquito/human contact increasing the probability of humans coming in contact with infective mosquitoes.

Mosquito Biology

Our assessment of the impact of solutions to drainage related problems was limited to 4 mosquito species: *Culex tarsalis*, *Culex quinquefasciatus*, *Aedes melanimon* and *Aedes nigromaculis*. These species occur in high abundance in the western San Joaquin Valley. *Aedes nigromaculis* is not considered an important vector of viruses but is a prime pest in the southern San Joaquin Valley (Bohart and Washino 1978). All 4 species will feed readily on humans.

Culex tarsalis larvae are found in a wide variety of habitats though they are primarily associated with agricultural sources including flooded pastures, irrigation seepage and tail water (Bohart and Washino 1978). This species is known to tolerate water with salinity up to 1% NaCl (Telford 1958). Eggs are laid on the water surface in egg rafts.

Culex quinquefasciatus larvae are found in water with a high organic content (Bohart and Washino 1978). Eggs are laid on the water surface in egg rafts.

Aedes melanimon larvae are found in floodwater situations. Larvae are commonly found in irrigated pastures and wildlife areas which are subject to regular flooding cycles (Bohart and Washino 1978). Eggs are deposited on soil at the base of vegetation. The eggs remain dormant until the site is flooded and hatch within a short time period of flooding. *Aedes melanimon* is found in a wide range of salinities and is known to tolerate salt concentrations of over 1% (Bohart 1956).

Aedes nigromaculis is another floodwater mosquito with larvae found in most commonly in irrigated pastures. Eggs are deposited and hatched in the same manner as *Ae. melanimon*. *Aedes nigromaculis* is generally considered to be less tolerant of salinity than *Ae. melanimon* with larvae generally found in sources with low salinity. (Bohart and Washino 1978).

All 4 species occur most frequently in agricultural situations with irrigation water exploited as sources. Changes in agricultural practices may change the abundance and distribution of these mosquitoes by altering the number and distribution of potential larval sources. The abundance and distribution of adult mosquitoes could change dramatically if evaporation ponds and associated sources could be exploited as larval habitat. Of the 4 species, greater salinity in the aquatic systems of the western San Joaquin Valley may best be exploited by *Ae. melanimon* since it is recognized as more salt tolerant than the other species.

In the following chapters we will report on our assessment of the likelihood of mosquitoes exploiting evaporation ponds and associated habitats as larval sources and assess whether changes in the dynamics of adult mosquito populations have taken place in the western San Joaquin Valley.

CHAPTER 2. ASSESSMENT OF EVAPORATION PONDS AS MOSQUITO HABITAT

Introduction

Evaporation ponds were assessed as mosquito sources by inspecting ponds for evidence of mosquito larvae, interviewing mosquito abatement district (MAD) personnel to determine whether ponds have a positive history as larval sources and by testing the ability of *Cx. tarsalis* larvae to survive in water samples from evaporation ponds. Water quality analysis was conducted on the samples in which larval survivorship was tested.

Methods

Ponds were inspected in December 1989. Mosquito populations are not reproductively active at this time of year in the San Joaquin Valley making it unlikely that larvae would be detected. *Culex tarsalis* overwinter as adults in reproductive diapause, *Cx. quinquefasciatus* adults are quiescent due to low ambient temperatures and *Aedes melanimon* and *Ae. nigromaculis* overwinter in the egg stage (Bohart and Washino 1978)

Ponds were examined for evidence of previous mosquito breeding. Inspections were limited to in-series and unicellular wet ponds since unicellular dry ponds were empty during the winter.

Ponds and pond margins were searched for larval and pupal mosquito skins. Shed skins would suggest that a pond had served as a mosquito source. The types of aquatic insects present in the ponds were also recorded. Certain aquatic insects are commonly found in association with mosquito larvae so their

presence would suggest that conditions in that pond may support mosquito development at times when mosquitoes are reproductively active. Pond were also examined for vegetation associated with larval sources. Pond edges were inspected for vegetation which could serve as oviposition substrate for *Aedes* mosquitoes. *Aedes melanimon* preferentially oviposit at the plant/soil interface of particular types of plants including salt grass (Reisen and Monath 1988).

The tolerance of *Cx. tarsalis* larvae to water conditions found in evaporation ponds was assessed by testing the ability of larvae to survive and develop in water samples from evaporation ponds. *Culex tarsalis* was chosen since it is the principle virus vector in the San Joaquin Valley (Reeves and Hammon 1962). Three newly laid egg rafts of a Davis strain colony of *Cx. tarsalis* were placed in a plastic containers containing 500 ml of water collected from designated evaporation ponds. Controls were placed in samples of distilled water and 1% and 5% saturated NaCl solutions. Three replicates of each treatment were used. Containers were checked daily for hatching. If hatching did not occur within 5 days samples were discarded. Samples were checked daily for pupation and mean pupation time calculated.

Water samples collected from evaporation ponds were analyzed by the DANR Diagnostic Laboratory at the University of California, Davis. Samples were tested for electrical conductivity (EC), and concentrations of Ca, Mg, Na, SO_4 and Cl ions.

Pond Inspections and Interviews

Table 1 lists the names, locations, sizes and types of ponds inspected. Figure 1 gives the general location of each pond.

POND A Pond A consisted of 3 shallow cells with were approximately 75% dry. No larvae nor larval and pupal skins were found. Numerous brine flies congregated on the pond margin but no other insects were detected. Wading birds were observed feeding in all 3 cells. No vegetation was evident in the pond or along the cell margins. The pond was not a source of mosquitoes according to the local mosquito control operator.

POND B Pond B was a unicellular dry pond with approximately 98% of the pond dry at inspection. Water was however being pumped into the pond along the southern edge. No mosquito skins were found in or around the pond. Corixids (Insecta:Hemiptera) were present in the inflow water but many dead individuals were found at the edge of the advancing water margin. No birds were observed feeding in this pond. A light mineral crust coated the pond bottom. No vegetation was observed. The status of this pond as a source of mosquitoes in the past was not determined.

POND C Pond C was a wet unicellular pond. No mosquitoes or skins were found. Corixids and aquatic crustaceans were the only macro-invertebrates detected. Wading birds were observed feeding in the pond. No emergent macrophytes were observed but the pond supported extensive stands of filamentous green algae. Pond

margins were clear of vegetation except for the northern margin were salt grass was growing near the waterline. The pond was not a source of mosquitoes according to the local mosquito control operator.

POND D Pond D was an in-series pond. Only the first 2 cells contained water. No mosquitoes or their cast skins were detected along the margins of either cell. Both cells contained many species of aquatic insects many of which have been collected in conjunction with mosquito larvae and the mosquito fish Gambusia affinis. The cells were over 1 meter deep with abundant algal growth. The pond margin was completely covered with grasses. Ducks were observed in both cells. The mosquito control operator reported that this pond was a mosquito source and that mosquito fish used to control them.

POND E Pond E was an in-series shallow pond. The pond was approximately 50% dry at the time of inspection with a heavy coating of precipitated minerals covering the pond bottom. The water contained mineral crystals suggesting complete saturation. No animals or vegetation was observed in or adjacent to this pond. Mosquito control operators were not interviewed concerning this pond since it was located outside of any mosquito abatement district.

POND F Pond F was an in-series pond. At the time of inspection, 3/6 cells were completely dry with differing amounts of mineral

deposition in each. Inspection of the remaining 3 cells failed to detect mosquito, their cast skins or the presence of aquatic insects. Two of the cells contained dead bullrushes, _Scirpus_ sp. though no living vegetation was detected in any 3 pond. The pond was not a source of mosquitoes according to the local mosquito control operator.

Culex tarsalis Survivorship and Development in Evaporation Pond Water

Culex tarsalis successfully hatched and developed into pupae in water collected from Ponds B and D. . Egg rafts placed on water collected from Ponds A, C, and E failed to hatch. Survivorship was not tested in water from Pond F. _Cx. tarsalis_ successfully pupated in distilled water and 1% NaCl but did not hatch in 5% NaCl.

Mean pupation times for larvae reared in water samples from Ponds B and D were not significantly different from larvae reared in distilled or 1 % NaCl. Mean pupation times ranged from 16 to 21 days.

Egg rafts placed on water samples from ponds A, C and E were desiccated with the opercula closed indicating no hatching. Rafts in other samples were empty with the opercula open and larvae present indicating successful hatching.

Water Quality and Mosquito Survivorship

Table 2 summarizes the results of testing of water samples used to test _Cx. tarsalis_ larval hatching and survivorship. The

water samples in which _Cx_. _tarsalis_ successfully survived to pupation had lower electrical conductivity readings and lower concentrations of Mg, Na, and SO_4 ions than water samples in which no hatching occurred. The results of these studies suggest that _Cx_. _tarsalis_ would fail to survive under conditions present in ponds A, C, and E during December 1989.

Discussion

Data from ponds A, C and E suggest that conditions in these ponds are unsuitable for _Cx_. _tarsalis_ survivorship at the study was conducted. It is likely that high salinity in these ponds prevented larval survivorship since larvae successfully pupated in water in which EC and specific ion concentrations were lower. These results suggest that high salinity may be an important barrier to certain ponds being sources of _Cx_. _tarsalis_. _Culex tarsalis_ larvae tolerate salinity up to 80% of ocean water but their upper salinity tolerance limited by their ion regulating mechanism (Bradley 1987).

Our results suggest that conditions in many ponds exceeded the physiological tolerance of _Cx_. _tarsalis_. If these conditions persisted during other times of the year it is highly unlikely that these ponds could serve as larval sources.

Our findings have shown that conditions suitable for larval development occur in at least 1 evaporation pond at the time of inspection. It is possible that other ponds which were not inspected or sampled could also support larval development.

Results from Pond D are inconclusive since the pond was over 90% dry when sampled. The water sample obtained from this pond was taken from in flow water. Larval survivorship in this sample suggests that subsurface drainage water being pumped into this pond is capable of supporting *Cx. tarsalis* development. This indicates that storage ponds and canals used to transport drainage water to evaporation ponds may be sources of *Cx. tarsalis*.

Additional studies involving the continuous monitoring of water quality in evaporation ponds would be required to determine the extent to which conditions in the ponds permit larval development during other times of the year. In addition, similar studies need to be conducted on other evaporation ponds so to assess their potential as mosquito sources. Also investigations need to be conducted as to the role of pond associated sources such as storage ponds and canals as mosquito sources.

Table 1. Evaporation ponds inspected for evidence of mosquito breeding activity, 1989-1990. (Data from SJVDP 1989).

Pond	Name	County	Year of First Operation	Size in Acres
A	Stone Land Company	Kings	1984	210
B	Barbizon Farms	Kings	1985	100
C	Westlake Farms North	Kings	1984	810
D	Meyers Ranch	Kings	1983	80
E	Westfarmers	Kern	1984	670
F	Sumner Peck	Fresno	1984	100

Figure 1. The location of evaporation ponds which were inspected and water samples taken in December, 1989. Letters signify pond designation in text.

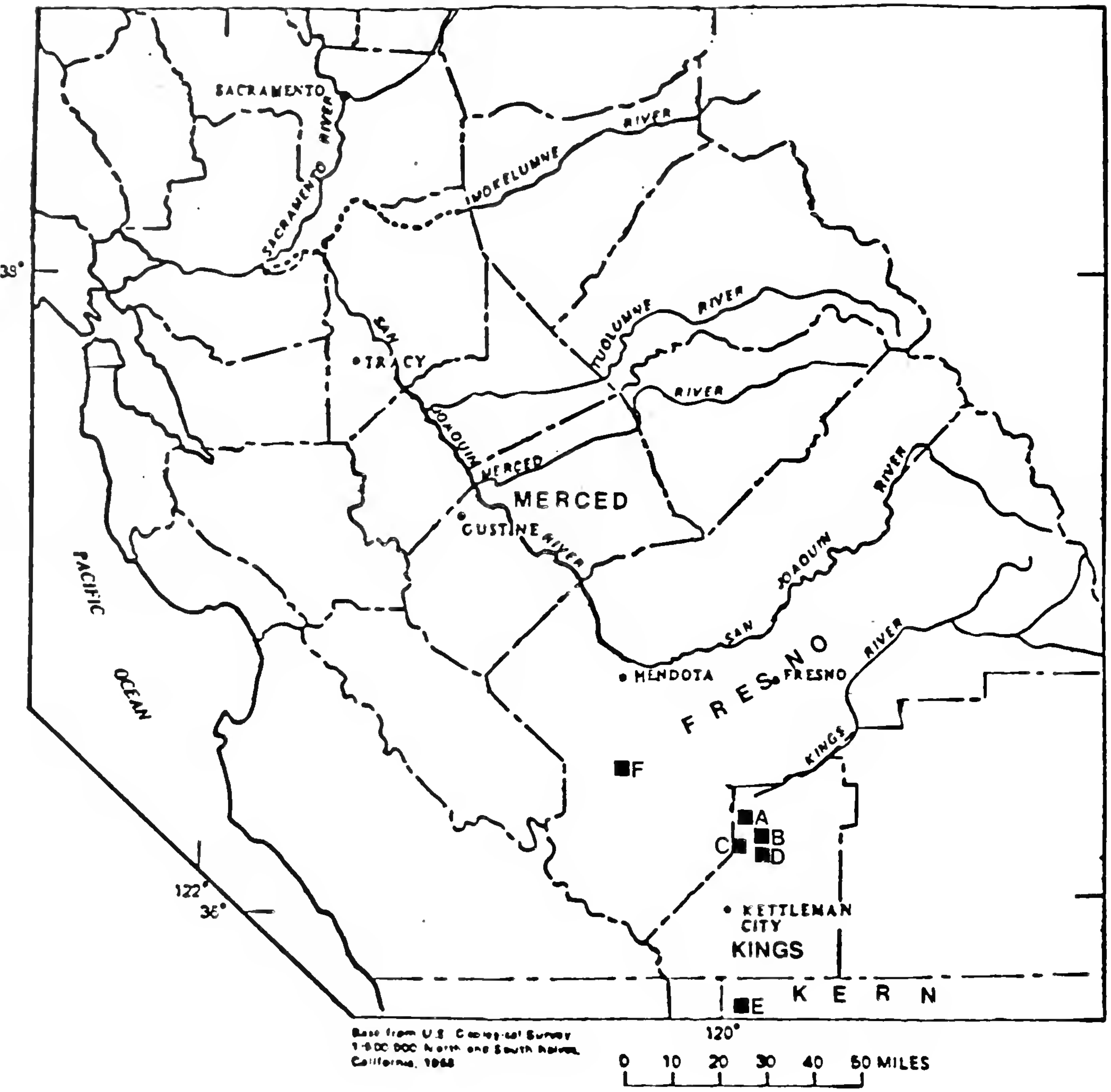
SACRAMENTO
SACRAMENTO RIVER
MOKELUMNE RIVER
TUOLUMNE RIVER
RIVER
SAN JOAQUIN
TRACY
MERCED
MERCED
RIVER
GUSTINE
SAN JOAQUIN RIVER
MENDOTA
FRESNO
FRESNO
KINGS RIVER
F
A
B
C
D
E
KETTLEMAN CITY
KINGS
KERN
PACIFIC
OCEAN
38°
36°
122°
120°
0 10 20 30 40 50 MILES

Table 2. Selected results of water quality analysis on water samples taken from evaporation ponds 1989-1990.

Pond	Sample	EC	Mg^a	Ca^a	Na^a	$SO_4{}^a$	Cl^a
A	1	111.8	3023	17	1344	2425	1834
A	2	64.3	320	28	970	1086	213
A	3	42.9	137	31	432	516	71
B	1@	17.9	32	2	201	208	9
B	2@	30.1	50	18	342	364	27
C	1	42	124	28	438	574	7
C	2	34.8	98	18	364	454	17
D	1@	13.5	84	6	80	133	27
D	2@	24.9	56	10	269	305	21
E	1	209	631	19	6130	2118	4607
F	1	*	2220	7	5348	3795	3635
F	2	*	28	33	348	255	151
F	3	*	16	27	151	158	33

EC - Electrical conductivity (millimhos/cm).
a - meq/l.
@ - Culex tarsalis larvae successfully emerged in water sample.
* - test not conducted.

CHAPTER 3. ABUNDANCE PATTERNS OF MOSQUITO POPULATIONS IN THE WESTERN SAN JOAQUIN VALLEY

Objectives

The objectives of this study were to describe the seasonal abundance patterns of the 4 most abundant mosquito species in the western San Joaquin Valley and determine whether seasonal and yearly abundance has undergone changes in recent years. Changes in seasonal dynamics and abundance may be the result of responses to drainage-related problems.

Methods

Abundance patterns for *Cx. tarsalis*, *Cx. quinquefasciatus*, *Ae. melanimon* and *Ae. nigromaculis* in the western San Joaquin Valley were studied by compiling and examining New Jersey light trap records provided by the Merced County, Fresno-Westside and Kings Mosquito Abatement Districts.

New Jersey light traps are used to monitor mosquito relative abundance by comparing the numbers of individuals of a species collected in the light trap per week. Mosquitoes are attracted to a light source in the trap, pulled into the trap in a down draft created by a rotating fan blade and collected in a receptacle in the trap. Traps are usually run nightly from spring to fall with the contents of the trap collected, sorted by species and counted weekly. Light traps have been operated in the same locations for a many years and have been used to monitor long term trends in mosquito abundance (Milby and Reeves 1986).

Light trap counts are used to assess the effectiveness of control efforts by mosquito abatement districts. High light trap counts of Cx. tarsalis have been associated with increase WEE virus activity in the San Joaquin Valley (Reisen and Monath 1989).

Mosquito species differ in the extent to which they are attracted to light traps (Service 1977) so numerical comparisons between species should not be made. Seasonal abundance patterns can be compared by determining what times of year peak abundance is attained for each species. Differences in the times when peak abundance is attained may suggest that 2 species are utilizing different types of sites as larval habitat. Changes in peak abundance times for a species may suggest a shift in the availability of suitable larval habitat.

Yearly abundance was assessed by calculating yearly means of numbers of females collected per week for each location. Within season abundance patterns were examined by plotting the total number of females per week for each trap graphically. Seasonal abundance patterns were then compared for different years.

Light trap records were obtained for 4 locations in western Merced County for the years 1983-1989; Gustine, Los Banos, Dos Palos and South Dos Palos, for 6 sites in Fresno County for the years 1980-1989; the towns of Firebaugh, Mendota and Tranquility and rural Canuta, Five Points and Eagle Field, and for Stratford in Kings County for the years 1980 and 1982-1989. Data for 1981 for Stratford was not available. The location of these traps is seen in Figure 2.

Season Long Abundance Patterns

Appendix A contains weekly abundance data for light trap locations plotted graphically to illustrating seasonal abundance patterns.

Seasonal abundance of Ae. melanimon shows a similar pattern in all light traps examined. Population levels are generally low during the spring and summer and rise sharply during late summer and fall. This pattern likely reflects the close association of Ae. melanimon with seasonal wetlands which are flooded during late summer and fall to provide habitat for migratory waterfowl. These areas produce large broods of Ae. melanimon (Mortenson 1963).

The mean yearly abundance of Ae. melanimon was relatively unchanged in Gustine, Los Banos, Dos Palos, South Dos Palos, Tranquility, and Eagle Field (Tables 3 and 7) all of which are located near seasonal wetlands. Mean yearly abundance declined at Firebaugh and Mendota and Ae. melanimon has virtual disappearance from Stratford, Canuta and Five Points (Tables 7 and 11). These traps are located in areas of intensive agriculture.

Seasonal abundance patterns for Cx. tarsalis differ by location with peak abundance during mid summer in Merced County and Mendota, Firebaugh, Eagle Field and Stratford (Tables 5, 9 and 11). Populations at Canuta, Five Points and Tranquility in Fresno County (Table 9) showed a decline in summer abundance accompanied by a reduction in mean abundance and a shift in peak

abundance to the fall. Mean annual abundance appears to be unchanged in Merced County and Firebaugh, Mendota, Tranquility and Eagle Field (Tables 5, 9, 11) .

Culex quinquefasciatus also showed differences in abundance and seasonal dynamics by location. Populations in Gustine, Los Banos and Mendota generally occurred in highest abundance during the summer while those in Dos Palos and Tranquility were moderate during the summer and increase slightly in the fall. Populations in Dos Palos and Stratford decreased during summer with peak abundance shifting from summer to fall. A similar trend was observed in South Dos Palos, Canuta, Five Points and Stratford (Tables 10 and 11) and was accompanied by a very sharp decline in population levels in 1988 and 1989. Mean annual abundance estimates show no discernable trend in Gustine, Los Banos, Dos Palos, South Dos Palos, Firebaugh, Mendota, Tranquility and Eagle Field (Tables 6 and 10) though mean abundance varied considerably between years.

Mean annual abundance estimates and numbers collected per week for Ae. nigromaculis are lower than for the other 3 species making meaningful analysis difficult. Mean number collected per week was less than 1 female per week in the majority of traps. A sharp decline in abundance was however observed at Eagle Field (Table 8) and Stratford (Table 11). Low numbers provided limited information about seasonal abundance patterns though peaks in abundance occur most frequently during the fall.

Discussion

Declining abundance and a shift toward a fall peak in abundance suggests that the dynamics of mosquito populations in the western Fresno County and Stratford in Kings County have undergone significant changes in recent years compared to populations in Merced County. Declining abundance a populations peak abundance toward the fall suggests that the availability of summer larval sources has declined. High population levels of mosquitoes are associated with abundant larval habitat (Reisen and Monath 1989) and it is likely that the reverse is true as well.

Reductions in available larval habitat could be caused by a change from flood and furrow irrigation to other methods in response to drainage-related problems in this area. Other factors such as reduced water availability due to 3 years of subnormal snow pack in key water shed areas and local rainfall may also be responsible.

A more comprehensive study is needed to examine the possible relationship between changes in irrigation practices and mosquito abundance.

Figure 2. Locations of New Jersey Light Traps used to assess changes in abundance and seasonal dynamics of mosquito populations in the western San Joaquin Valley. A - Gustine, B - Los Banos, C - Dos Palos, D - South Dos Palos, E - Firebaugh, F - Mendota, G Tranquility, H - Canuta, I - Five Points, K - Stratford.

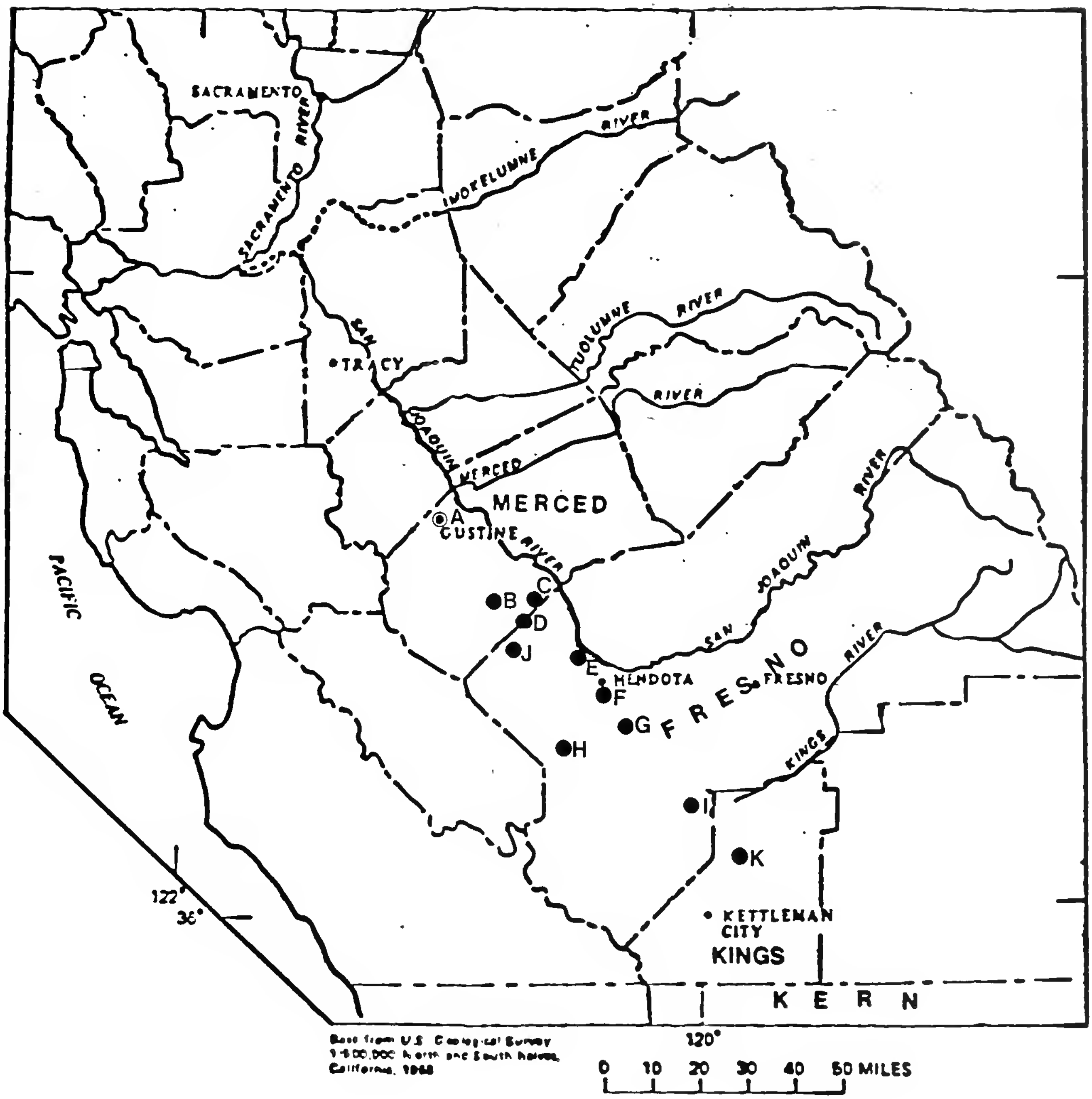
SACRAMENTO
SACRAMENTO RIVER
MOKELUMNE RIVER
TUOLUMNE RIVER
SAN JOAQUIN
TRACY
MERCED
MERCED RIVER
A
GUSTINE
B
C
D
J
E
MENDOTA
F
G
H
I
K
FRESNO
SAN JOAQUIN RIVER
KINGS RIVER
KETTLEMAN CITY
KINGS
KERN
PACIFIC OCEAN
122°
36°
120°
Base from U.S. Geological Survey
0 10 20 30 40 50 MILES

Table 3. Annual mean number of *Aedes melanimon* females collected per week in New Jersey light traps located in western Merced County, California 1983-1989. (Compiled from Merced County Mosquito Abatement District records).

Year	Gustine	Los Banos	Dos Palos	South Dos Palos
1983	17.1	22.0	1.9	8.6
1984	26.2	10.1	2.5	28.6
1985	37.9	17.25	3.2	38.3
1986	20.6	1.7	0.6	50.0
1987	75.5	12.0	2.4	21.3
1988	25.9	15.6	1.5	14.9
1989	21.2	23.8	4.0	20.9

Table 4. Annual mean number of *Aedes nigromaculis* females collected per week in New Jersey light traps located in western Merced County, California 1983-1989. (Compiled from Merced County Mosquito Abatement District records).

Year	Gustine	Los Banos	Dos Palos	South Dos Palos
1983	1.0	0.9	2.6	0.7
1984	0.3	0.4	2.0	0.6
1985	0.9	0.3	0.5	0.5
1986	1.2	0.1	0.2	0.2
1987	0.4	0.1	0.8	0.4
1988	1.0	0.2	0.4	0.1
1989	1.1	0.1	0.9	0.6

Table 5. Annual mean number of *Culex tarsalis* females collected per week in New Jersey light traps located in western Merced County, California 1983-1989. (Compiled from Merced County Mosquito Abatement District records).

Year	Gustine	Los Banos	Dos Palos	South Dos Palos
1983	1.6	1.3	0.8	1.8
1984	1.5	0.9	1.3	2.4
1985	1.8	1.1	0.6	2.4
1986	2.2	0.3	0.7	2.0
1987	1.8	0.8	0.6	2.2
1988	1.5	1.0	0.6	1.8
1989	1.8	0.6	1.2	1.4

Table 6. Annual mean number of *Culex quinquefasciatus* females collected per week in New Jersey light traps located in western Merced County, California 1983-1989. (Compiled from Merced County Mosquito Abatement District records).

Year	Gustine	Los Banos	Dos Palos	South Dos Palos
1983	3.1	1.5	0.5	0.6
1984	2.3	0.6	3.7	1.6
1985	6.3	9.0	0.9	1.0
1986	5.3	3.1	0.5	1.5
1987	5.0	1.7	2.2	0.4
1988	2.7	1.8	0.6	0.6
1989	3.4	1.8	2.6	2.4

Table 7. Annual mean number of *Aedes melanimon* females collected in New Jersey light traps in western Fresno County, California 1980-1989. (Compiled from Fresno-Westside Mosquito Abatement District records).

Year	FIR	MEN	TRA	CAN	5PT	EAG
1980	5.9	2.1	2.2	2.4	0.4	305
1981	10.4	3.6	6.6	1.3	0.1	308
1982	17.2	5.5	16.8	3.5	0.4	308
1983	2.9	3.4	12.6	1.6	0.3	98
1984	0.6	0.5	2.2	0.2	0.1	23
1985	1.9	1.4	4.9	0.9	0.3	62
1986	4.6	.8	3.5	0.7	1.2	93
1987	3.8	2.5	25.1	2.1	0.6	290
1988	1.7	.6	7.2	0.1	0	175
1989	1.6	1.9	22.0	0.2	0	185

FIR - Firebaugh.
MEN - Mendota.
TRA - Tranquility.
CAN - Canuta.
5PT - Five Points.
EAG - Eagle Field.

Table 8. Annual mean number of Aedes nigromaculis females collected in New Jersey light traps in western Fresno County, California 1980-1989. (Compiled from Fresno-Westside Mosquito Abatement District records).

Year	FIR	MEN	TRA	CAN	5PT	EAG
1980	0.2	0.5	0.8	5.6	1.5	62.6
1981	0.8	1.2	4.4	1.3	0.2	6.7
1982	0.3	0.6	5.8	0.2	0.3	8.9
1983	0.4	0.8	2.3	1.2	0.3	11.5
1984	0.5	0.2	0.8	0.2	0.3	1.2
1985	0.2	0.3	0.6	0.4	0.3	3.7
1986	0.6	0.1	0.4	0.4	0.1	0.9
1987	0.2	0.1	0.9	0.2	0.2	0.5
1988	0.5	0.1	0.9	0.1	0.1	1.6
1989	1.6	0.3	1.9	0.2	0.2	0.5

FIR - Firebaugh.
MEN - Mendota.
TRA - Tranquility.
CAN - Canuta.
5PT - Five Points.
EAG - Eagle Field.

Table 9. Annual mean number of Culex tarsalis females collected in New Jersey light traps in western Fresno County, California 1980-1989. (Compiled from Fresno-Westside Mosquito Abatement District records).

Year	FIR	MEN	TRA	CAN	5PT	EAG
1980	9.8	6.1	4.6	6.5	4.8	126.9
1981	26.5	7.9	11.4	9.9	7.0	55.9
1982	12.6	6.7	15.7	11.0	13.8	113.9
1983	17.4	5.0	10.7	14.4	5.2	50.2
1984	24.2	5.8	7.4	6.3	2.4	44.7
1985	18.5	1.6	6.8	9.6	2.6	54.7
1986	55.9	4.0	9.6	11.4	13.3	46.1
1987	19.5	2.4	27.3	8.9	3.5	69.9
1988	13.9	1.2	6.3	1.8	1.4	91.7
1989	8.5	2.5	6.8	0.8	0.3	34.2

FIR - Firebaugh.
MEN - Mendota.
TRA - Tranquility.
CAN - Canuta.
5PT - Five Points.
EAG - Eagle Field.

Table 10. Annual mean number of *Culex quinquefasciatus* females collected in New Jersey light traps in western Fresno County, California 1980-1989. (Compiled from Fresno-Westside Mosquito Abatement District records).

Year	FIR	MEN	TRA	CAN	5PT	EAG
1980	8.4	0.8	1.1	1.8	1.5	2.2
1981	5.4	0.9	1.6	0.9	7.4	2.5
1982	2.7	2.0	0.9	0.9	6.5	3.6
1983	5.1	1.8	1.9	1.9	5.1	6.4
1984	5.1	1.9	1.1	0.4	4.0	0.2
1985	18.5	1.2	1.2	0.7	10.7	4.7
1986	4.5	1.8	1.9	1.2	15.1	0.3
1987	4.3	10.8	1.6	6.7	5.9	7.4
1988	2.7	1.5	0.9	0	0.6	1.3
1989	10.9	3.3	1.8	0.2	0.5	3.3

FIR - Firebaugh.
MEN - Mendota.
TRA - Tranquility.
CAN - Canuta.
5PT - Five Points.
EAG - Eagle Field.

Table 11. Annual mean number of *Aedes melanimon*, *Culex tarsalis*, *Culex quinquefasciatus* and *Aedes nigromaculis* females collected in a New Jersey light trap located in Stratford, Kings County, California 1980, 1982-1989. (Compiled from Kings Mosquito Abatement District records, No records were available for 1981)

Year	Aedes melanimon	Culex tarsalis	Culex quinquefasciatus	Aedes nigromaculis
1980	3.7	22.4	2.7	4.2
1982	4.0	9.0	4.8	27.1
1983	3.5	13.9	16.9	0.2
1984	0.7	4.2	2.7	0.3
1985	0.4	1.7	5.8	0.1
1986	0.4	2.9	2.4	0.3
1987	0.1	1.1	12.7	6.1
1988	0.1	0.7	8.8	0.4
1989	0.0	2.5	11.4	0.3

CHAPTER 4. SUMMARY AND RECOMMENDATIONS

General Summary

The survey of evaporation ponds, the Cx. tarsalis larval survivorship trial and water quality analysis suggest that high salinity may be a barrier to utilization of evaporation ponds by Cx. tarsalis as larval habitat.

Water samples from ponds with high salinity failed to support Cx. tarsalis development while development took place in water samples from ponds with lower salinity. These studies also showed that salinity varied considerably between ponds and in different cells in the same pond. Similar observations were made by Wescott et al. (1988).

It was not possible to determine whether the salinity of water in highly saline evaporation ponds remained at sufficiently high concentrations to prevent Cx. tarsalis breeding during the entire season since sampling was limited to the winter. At least 1 pond could likely serve as a source of Cx. tarsalis and since the water quality in evaporation ponds is likely to vary considerably it is possible that other ponds could serve as mosquito habitat as well. More extensive sampling of evaporation ponds needs to take place to determine if additional ponds could serve as larval habitat.

Examination of light trap records from locations in the western San Joaquin Valley indicate that mosquito abundance and seasonal abundance patterns have undergone changes in some geographic areas but not in others. The area in which the greatest changes have occurred is rural western Fresno County and

northwestern Kings County where drainage-related problems have become a significant barrier to agriculture in recent years. Changes in irrigation practices in response to increasing drainage-related problems may have reduced the available larval habitat resulting in decreased summer populations of mosquitoes. This hypothesis needs to be investigated further.

Recommendations

1) Participation of Mosquito Abatement Districts in San Joaquin Valley Drainage Project

The mosquito abatement districts which serve areas covered by the San Joaquin Valley Drainage Program should be involved in the drainage program. The mosquito abatement districts can provide suggestions to minimize mosquito production in implementing alternatives for solving drainage-related problems. Their input may play an important role in preventing increases in the incidence of mosquito transmitted diseases by minimizing the potential for mosquito production which is associated with certain alternatives to drainage related problems.

2) Inspection and Water Quality Monitoring of Evaporation Ponds

The field studies assessing the suitability of evaporation ponds as mosquito habitat were limited in scope due to the time of year in which these studies were conducted. Full assessment of the potential of evaporation ponds as mosquito habitat would require regular monitoring of water quality in evaporation ponds

across the mosquito breeding season. Water quality in evaporation ponds changes with time (Wescott et al. 1988) so these changes need to be continuously monitored in order to fully assess whether individual ponds could support mosquito populations.

3) Determine the Extent to Which Canals and Ponds Used to Store Drainage Water Are Used as Larval Habitat by Mosquitoes.

Culex tarsalis developed normally in water samples obtained where water was flowing into Pond D. This suggested that unconcentrated drainage water could support Cx. tarsalis development and that storage ponds and drainage canals should be evaluated as possible sources of mosquitoes.

4) Assessing the Tolerance of Mosquito Larvae to High Salinity

The studies on larval survivorship focused on Cx. tarsalis since this is the principle vector species in the San Joaquin Valley (Reeves and Hammon 1962) but the tolerance of other mosquito species to water conditions found in evaporation ponds should also be assessed. Aedes melanimon is known to be tolerant to moderate salinity and could potential exploit evaporation ponds as larval habitat. Aedes dorsalis, a species closely related to Ae. melanimon (Bohart and Washino 1978), has been reported in western Fresno and Merced County and is known to be highly tolerant to salinity. Evaporation ponds could form a new habitat in which this species could breed and increase in abundance in the San Joaquin Valley. The salinity tolerance of

these and other species found in the western San Joaquin Valley should be determined.

In-series evaporation ponds may offer an ideal situation to study the tolerance of mosquitoes and other invertebrates to decreases in water quality caused by increased salinity. Differences in water quality between cells can be used to study the tolerance of mosquitoes and other organisms to different salt concentrations in the field. Similar types of studies have been conducted in sewage oxidation ponds (Fisher et al. 1972).

5) Monitoring of Adult Mosquito Abundance

Analysis of light trap records from the western San Joaquin Valley suggest that there has been an overall decline in mosquito populations in western Fresno and Kings Counties. This decline may be associated with changes in water management induced by drainage related problems. Further monitoring of mosquito populations in the western San Joaquin Valley is required to determine whether the decline in mosquito abundance is significant or the result of annuals fluctuations in abundance. Light trap records for the western San Joaquin Valley should continue to be monitored while additional methods should be used to monitor mosquito abundance in areas where no light traps are located.

Portable light traps should be placed adjacent to evaporation ponds to assess the adult mosquito population levels adjacent to the ponds in comparison to other sites in the same geographic area. Differences in population levels may indicate

the extent to which mosquitoes are attracted to and utilize evaporation ponds as larval habitat.

6) Comparative Irrigation Practices and Larval Source Survey

Further studies examining the relationship between responses to drainage related problems and the abundance of larval mosquito habitat are required to determine whether responses to drainage related problems have caused a reduction in larval habitat. An area which needs to be examined in detail is how differences in agricultural practices, water use and disposal practices differ between western Merced and Fresno Counties. Population levels and seasonal abundance patterns of *Cx. tarsalis* and *Cx. quinquefasciatus* have remained essentially unchanged in Merced County but have changed dramatically in Fresno County and a comparison of agricultural practices in the 2 areas combined with an extensive survey for larval habitat in the 2 areas could be used to determine the extent to which differences in agricultural practices may effect mosquito abundance.

7) Monitor for Arbovirus Activity

Determine the impact of changing patterns of mosquito abundance on virus activity in the western San Joaquin Valley. Activities would include testing mosquito pools for evidence of vector infection rates and establishing standard sentinel chicken flocks in the area to measure virus transmission rates.

8) Examine Other Vector-disease Systems which may be Effected by the San Joaquin Valley Drainage Program.

Other vector-disease systems that require further consideration include mosquito-canine heartworm and _Culicoides_ gnat-bluetongue in sheep and cattle. These systems have also be effected by changes in water usage and management practices. The _Culicoides_ gnat-bluetongue system may be very important since _Culicoides_ gnats are quite tolerant of breeding sites containing extremes in chemical parameters.

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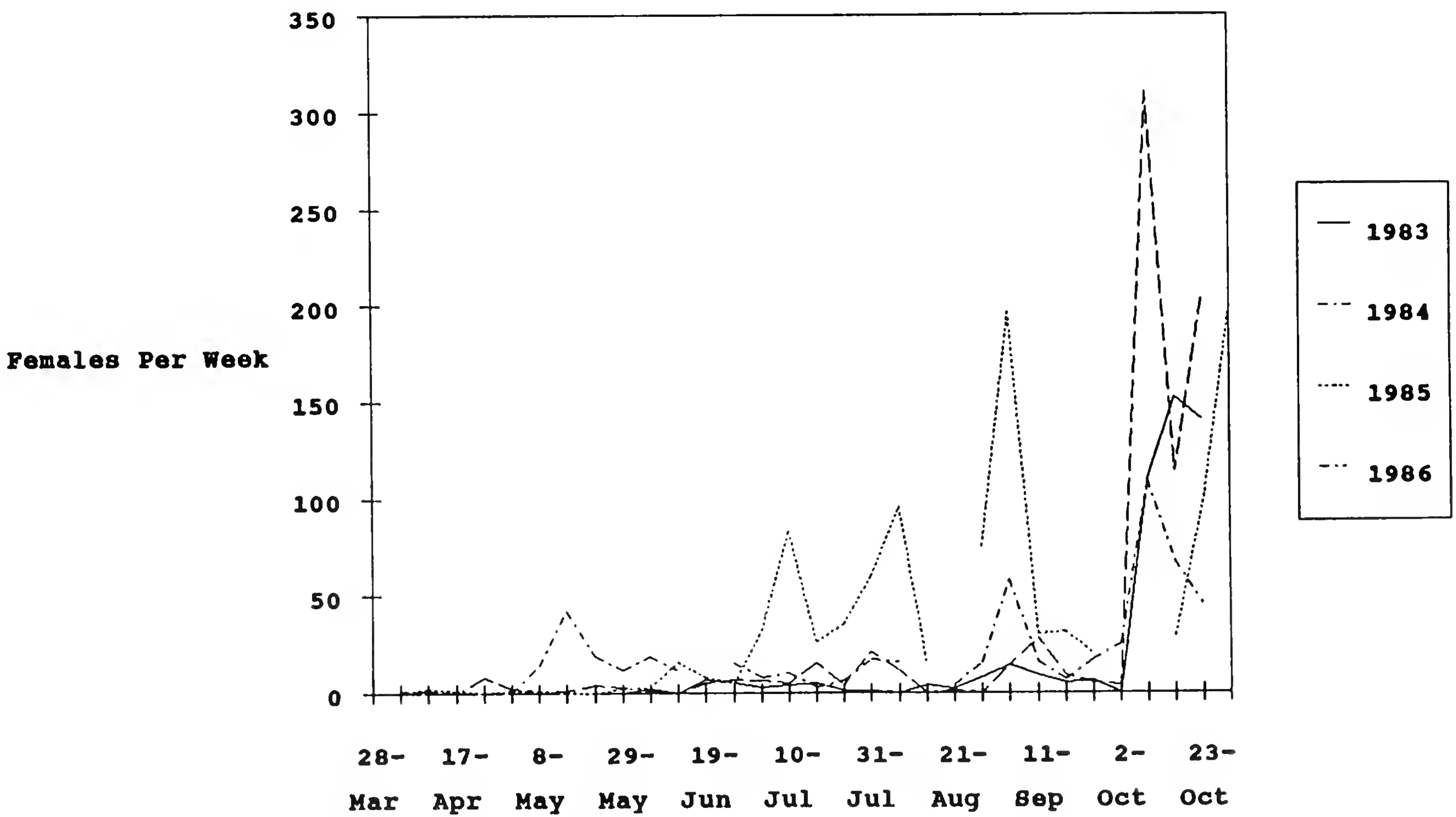
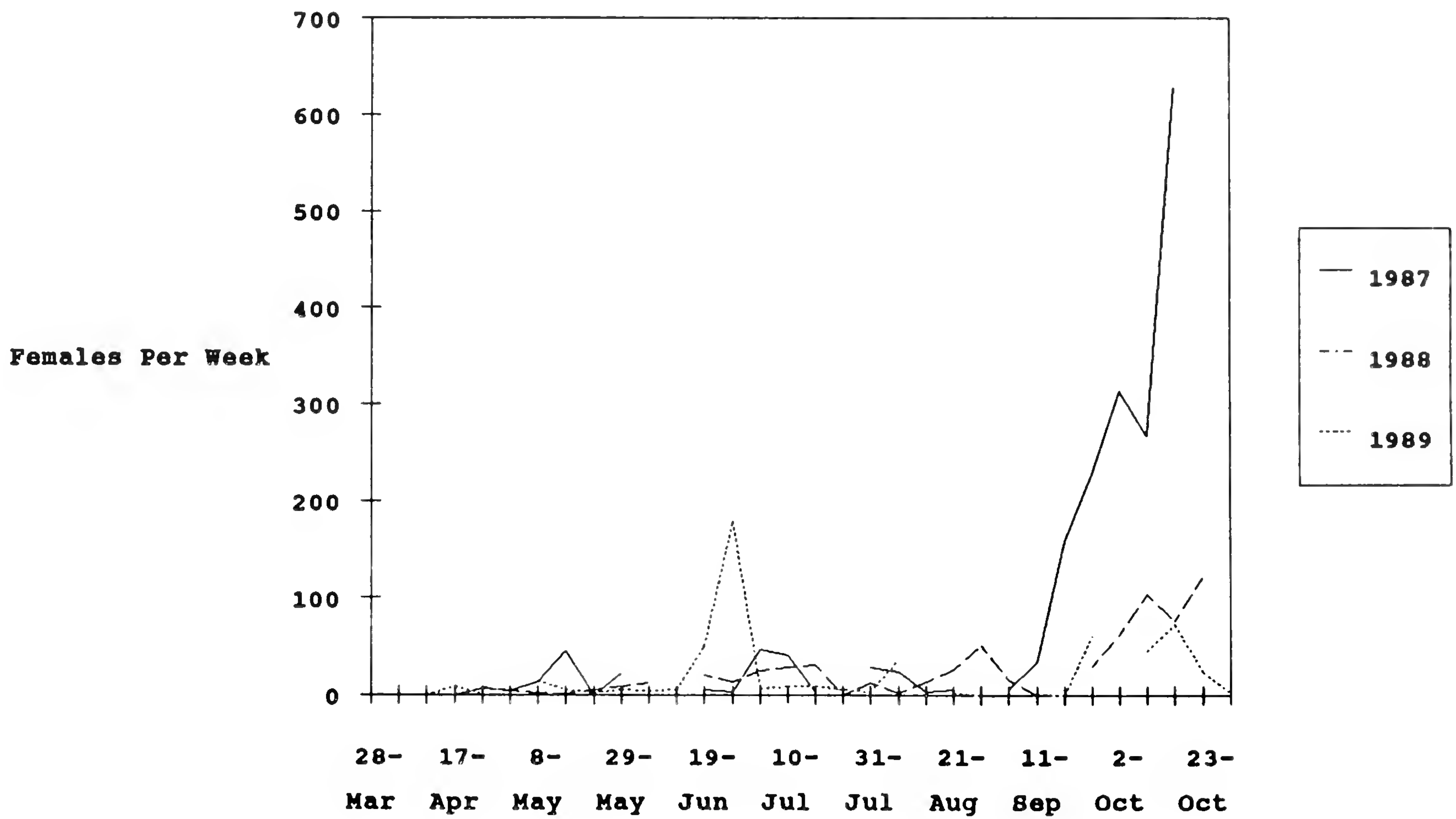
Appendix A. Numbers of *Aedes melanimon*, *Aedes nigromaculis*, *Culex tarsalis* and *Culex quinquefasciatus* collected in New Jersey light traps whose locationis indicated in Figure 2.

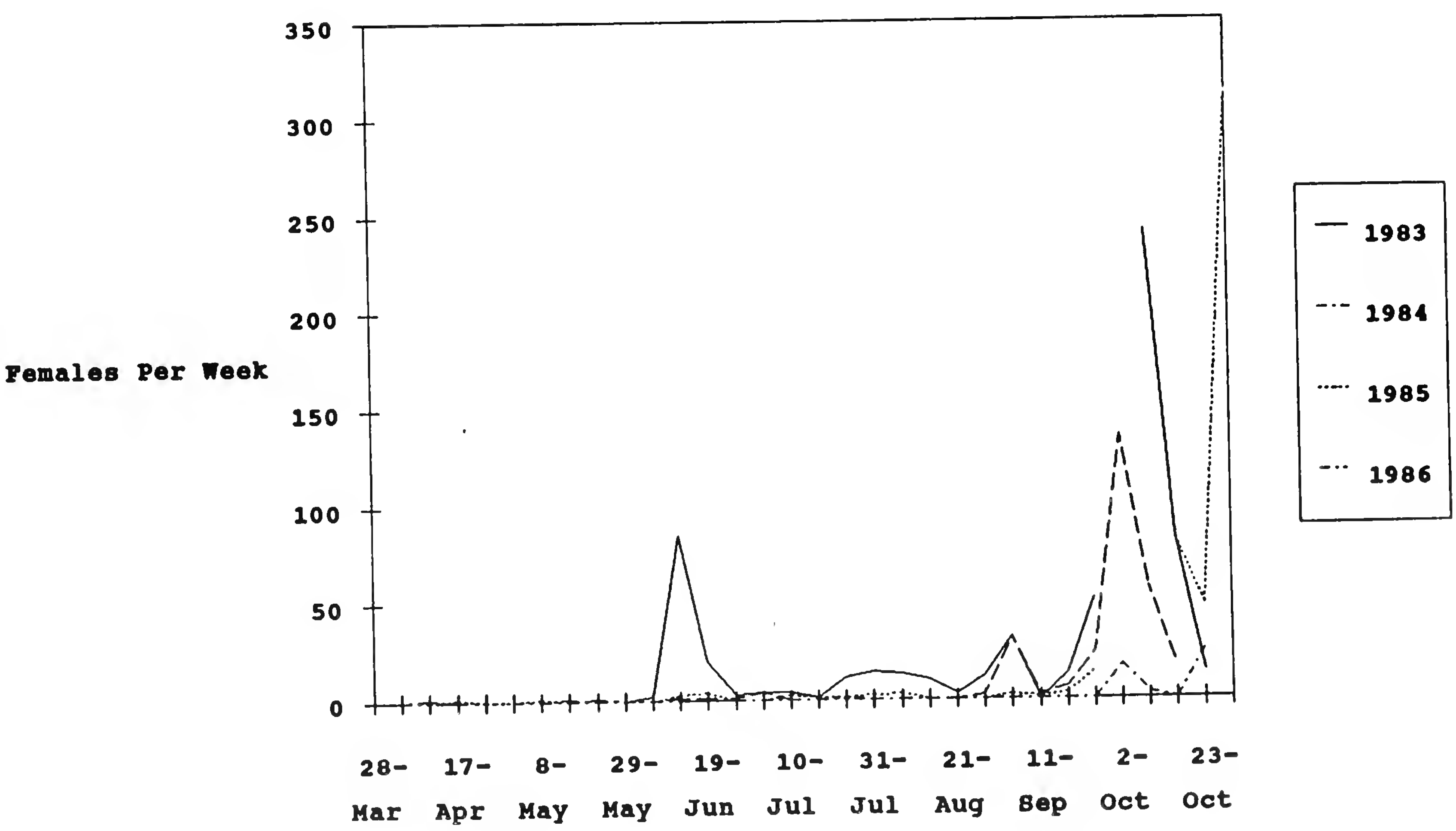
Aedes melanimon: Gustine

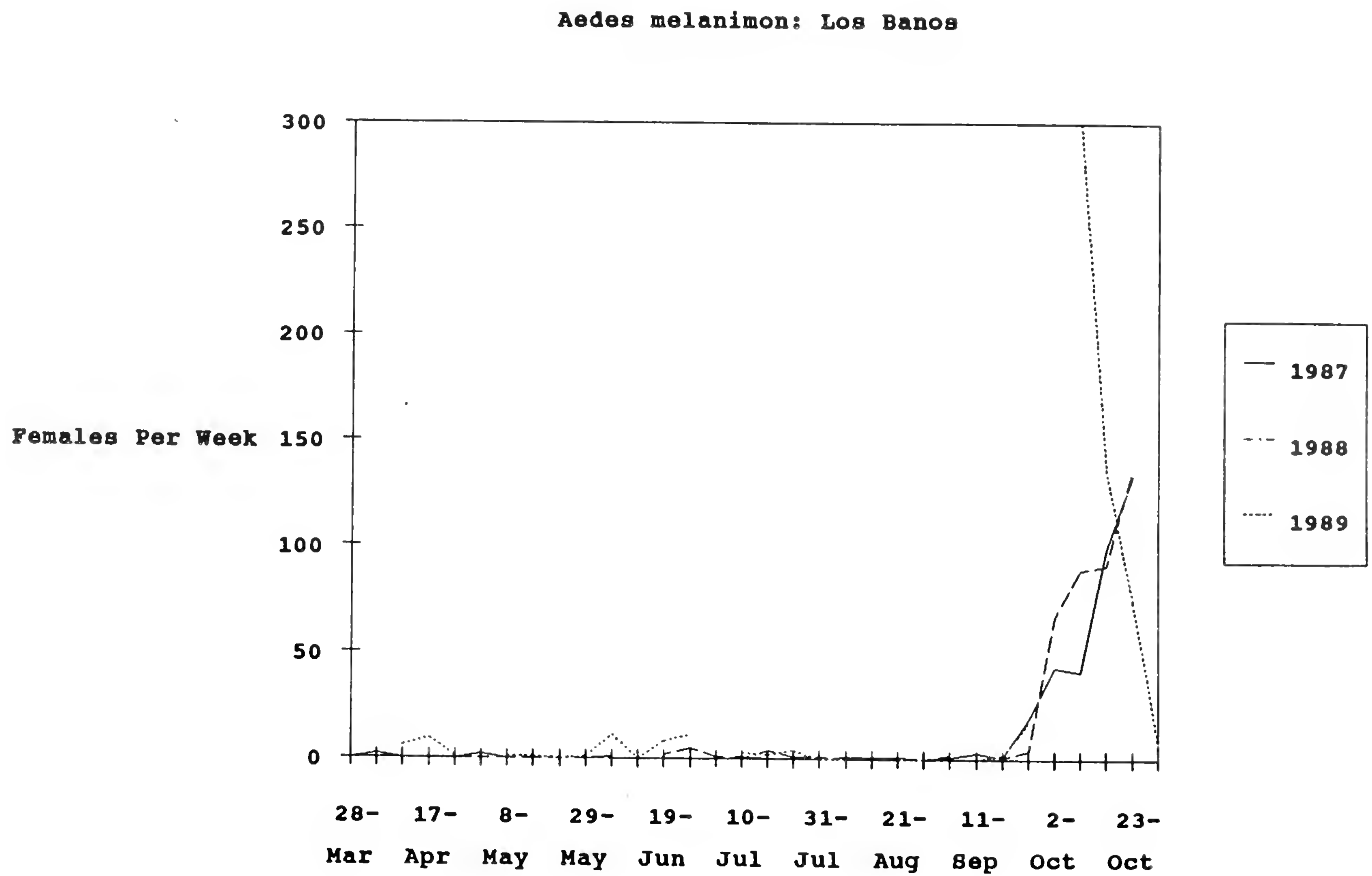


Aedes melanimon: Gustine

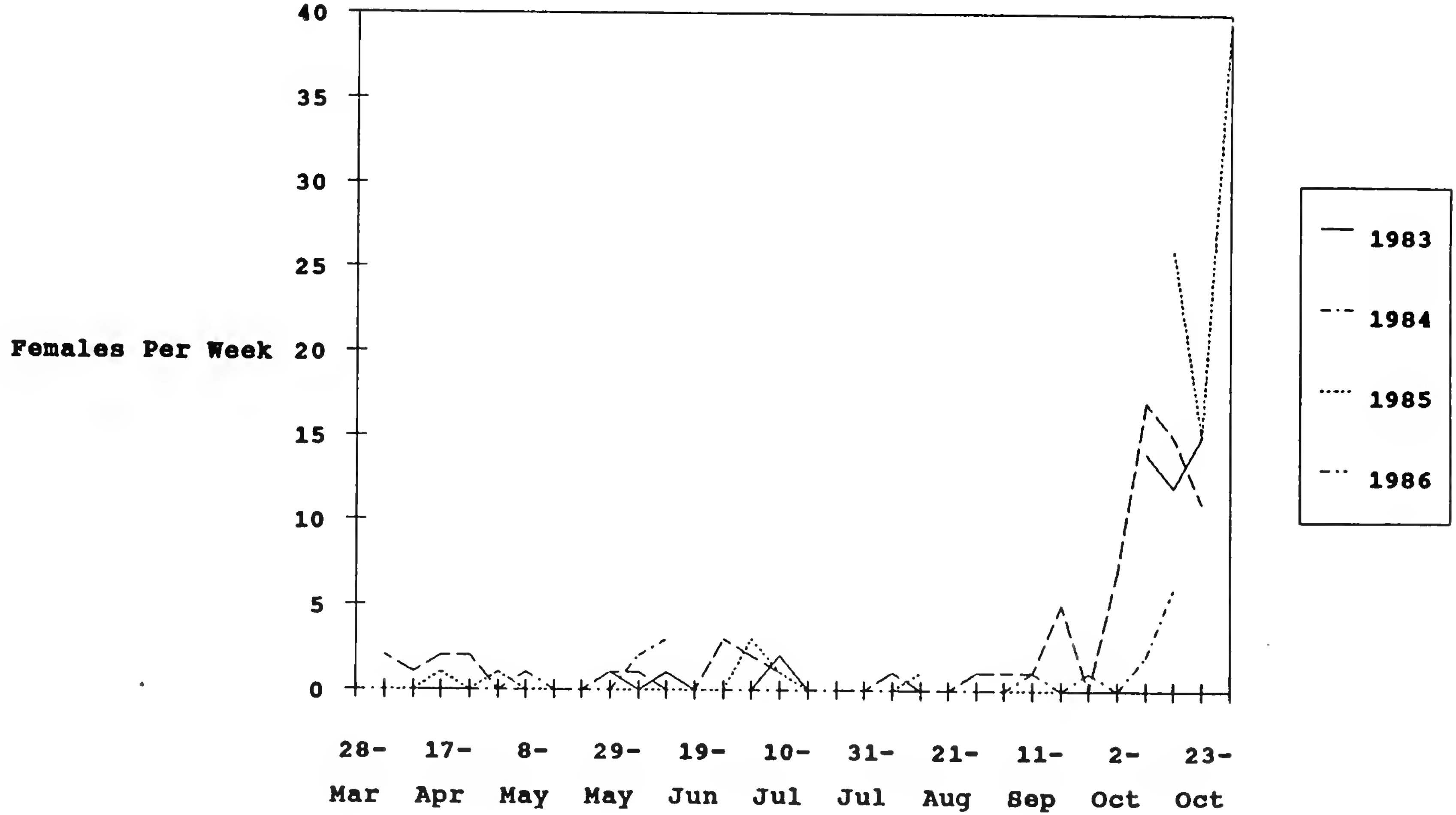


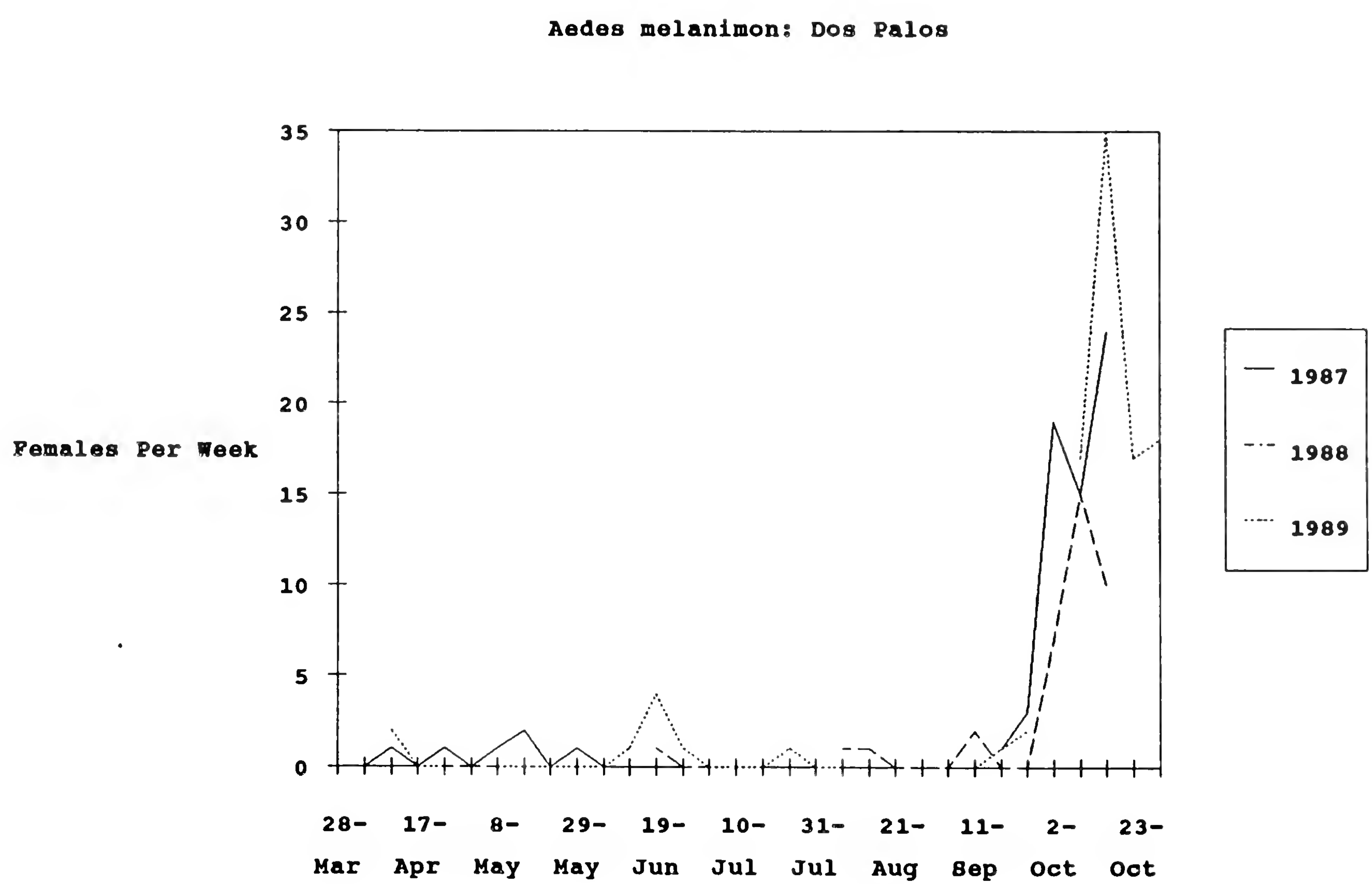
Aedes melanimon: Los Banos




Aedes melanimon: Los Banos
Females Per Week
300
250
200
150
100
50
0
28- Mar
17- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

Aedes melanimon: Dos Palos

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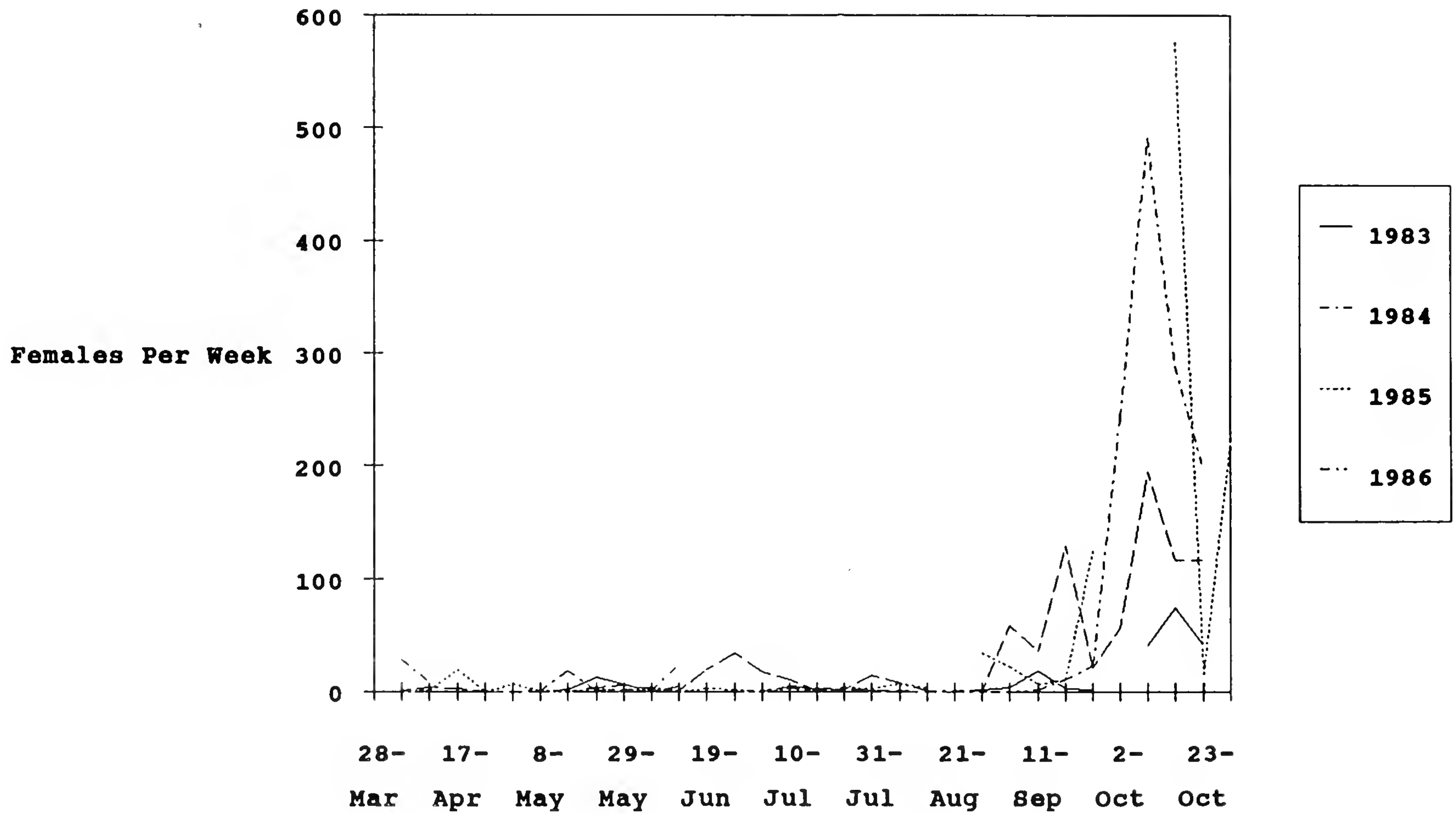
Females Per Week
0
5
10
15
20
25
30
35
28- Mar
17- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

Aedes melanimon: South Dos Palos



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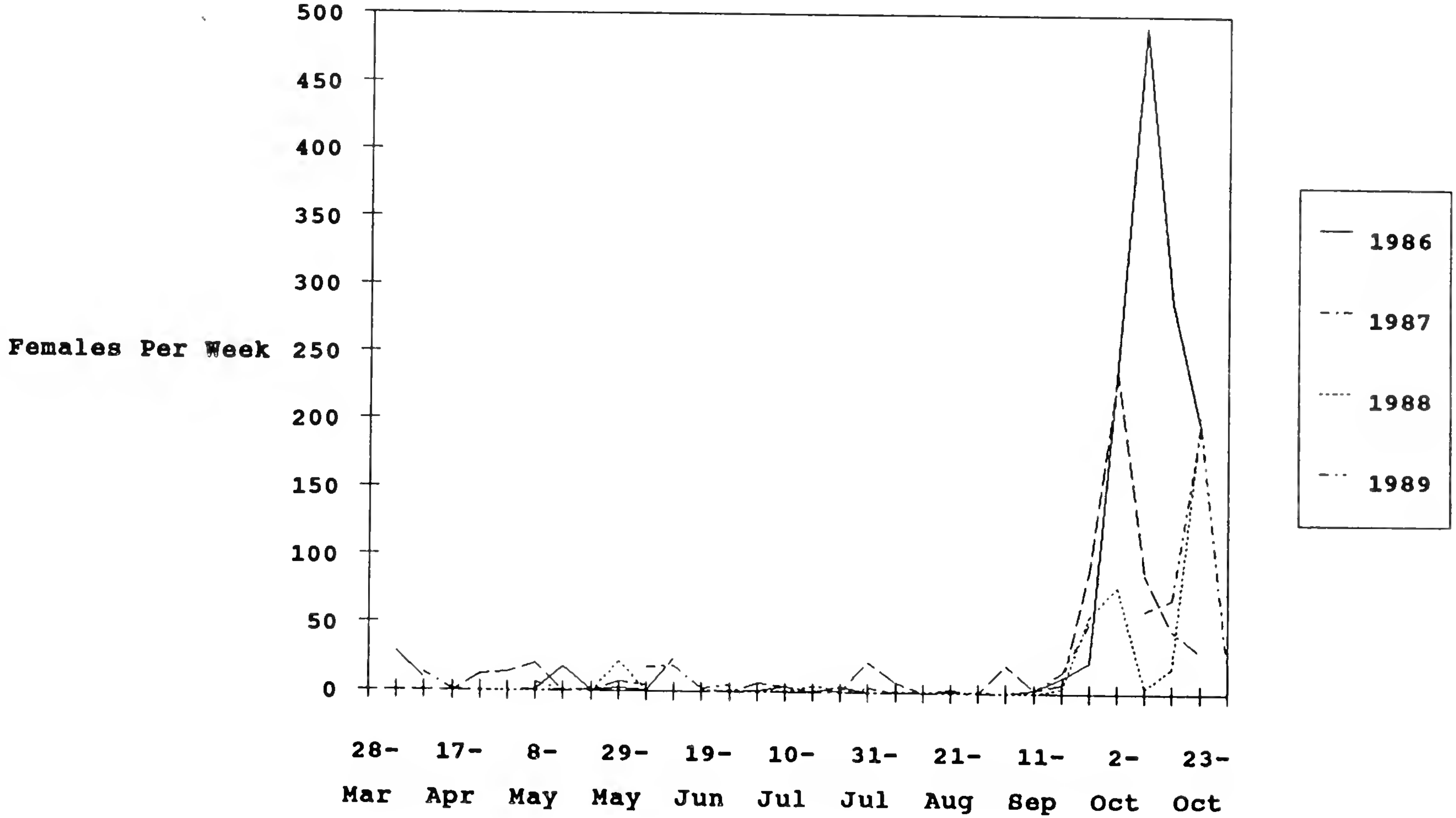
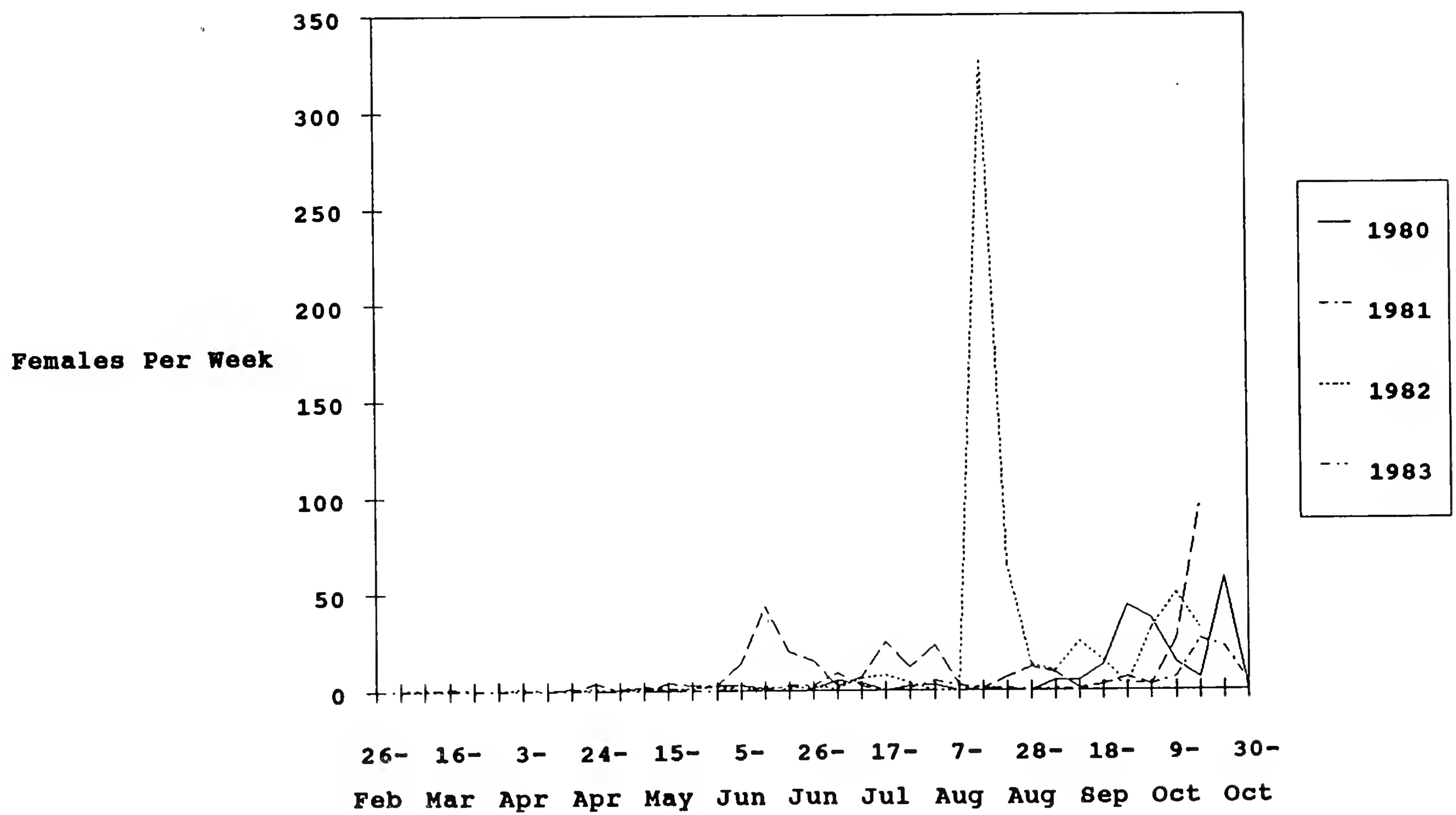
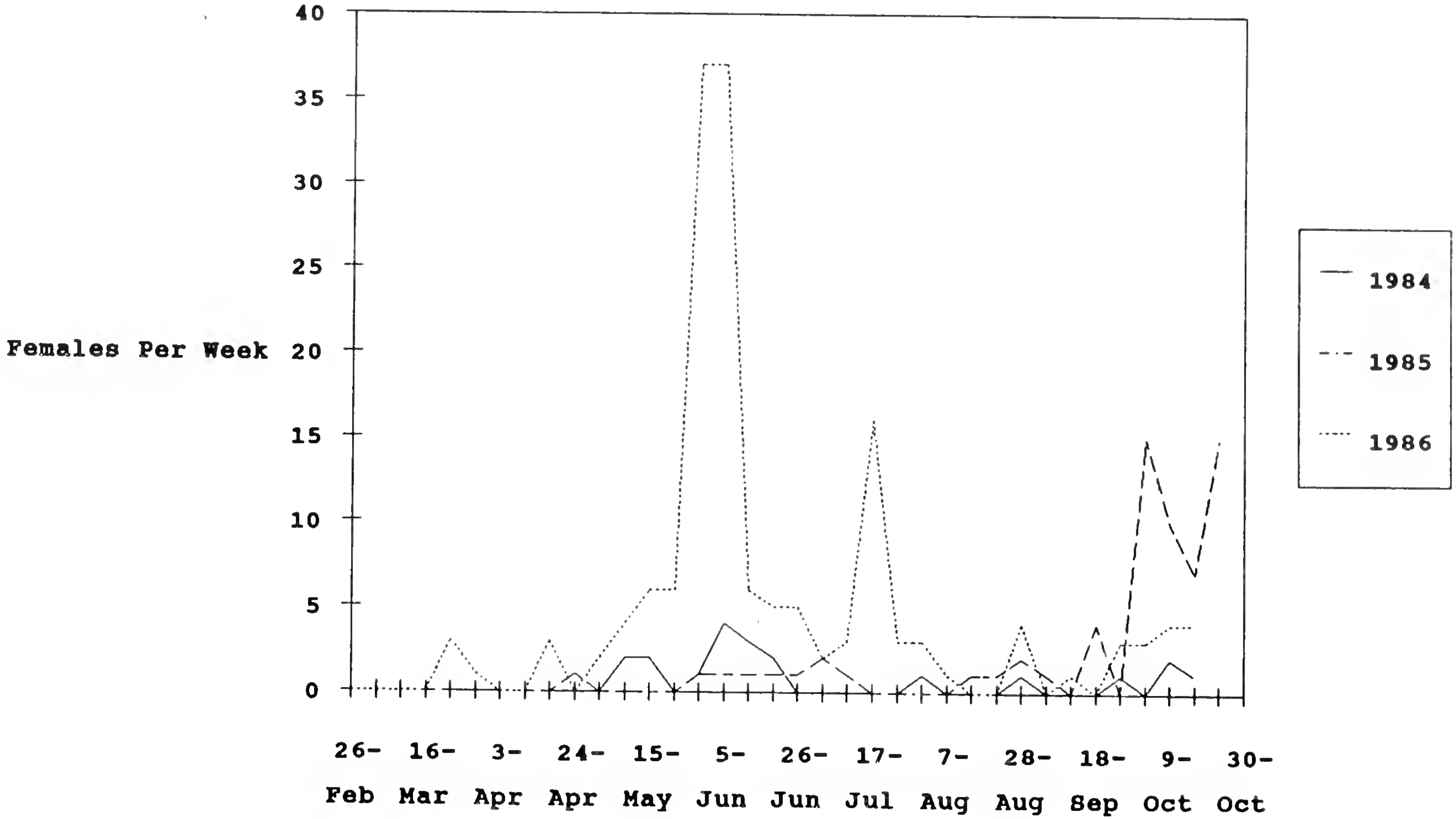
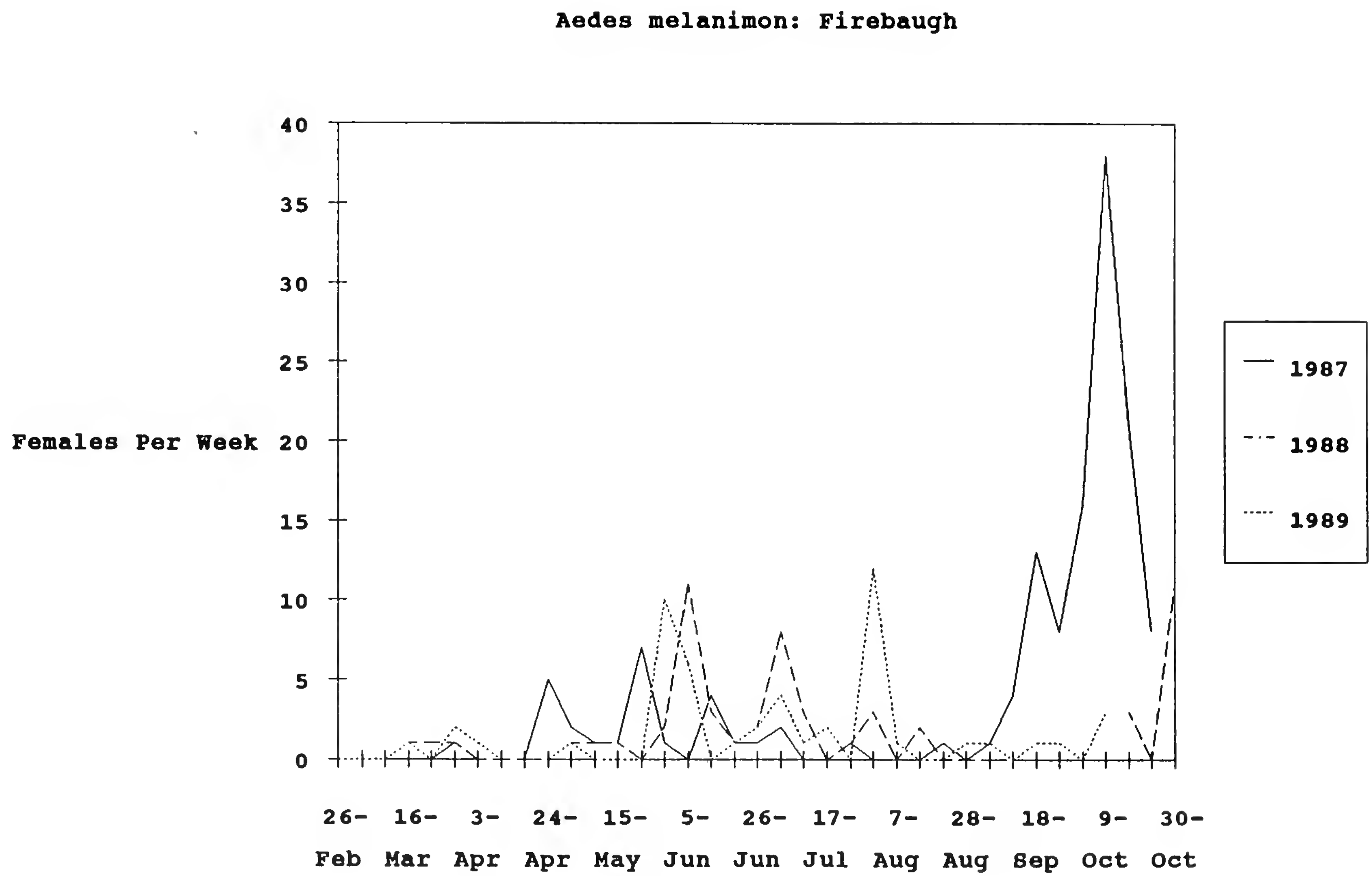


Aedes melanimon: Firebaugh

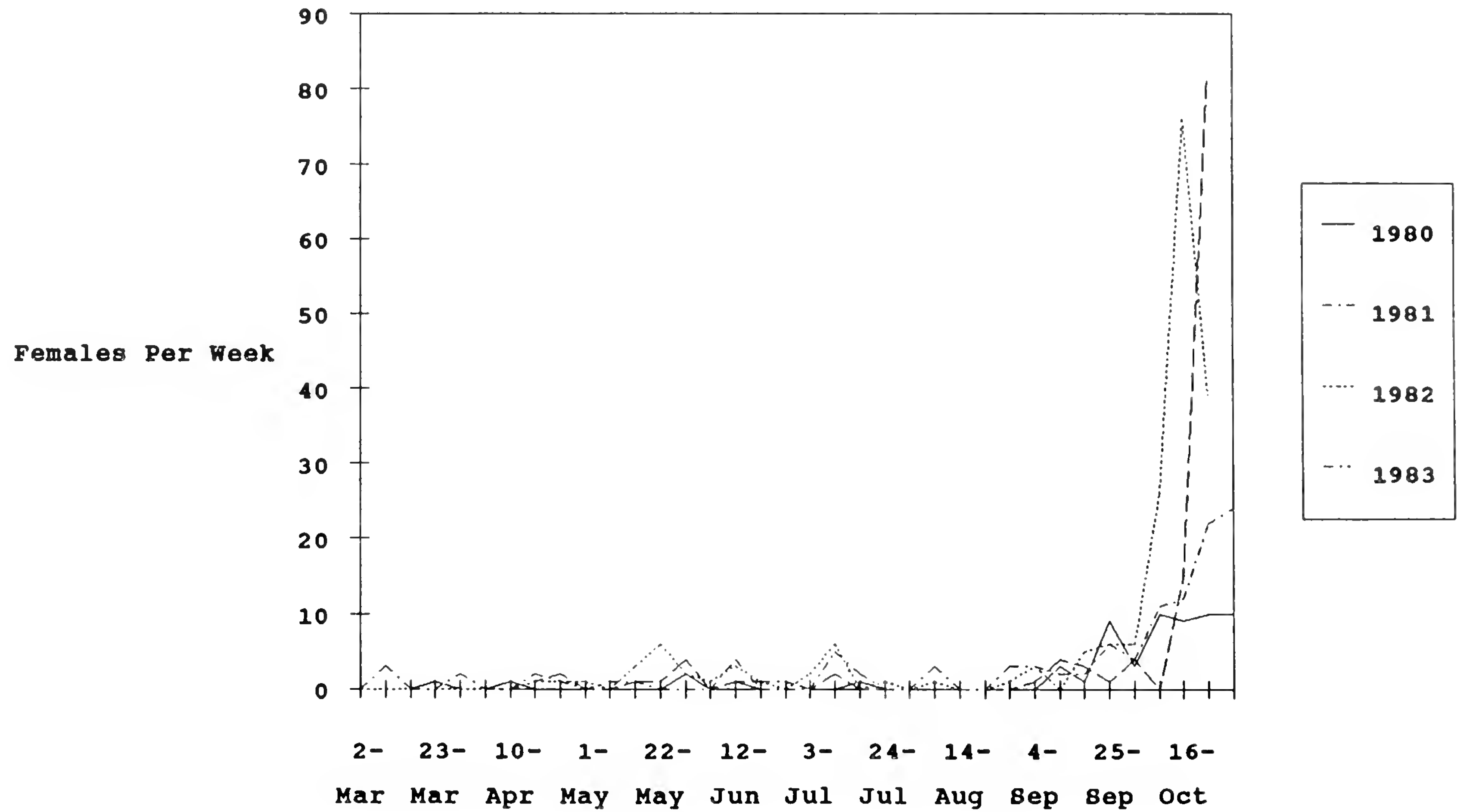


Aedes melanimon: Firebaugh




Aedes melanimon: Firebaugh
Females Per Week
40
35
30
25
20
15
10
5
0
26- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1987
1988
1989

Aedes melanimon: Mendota



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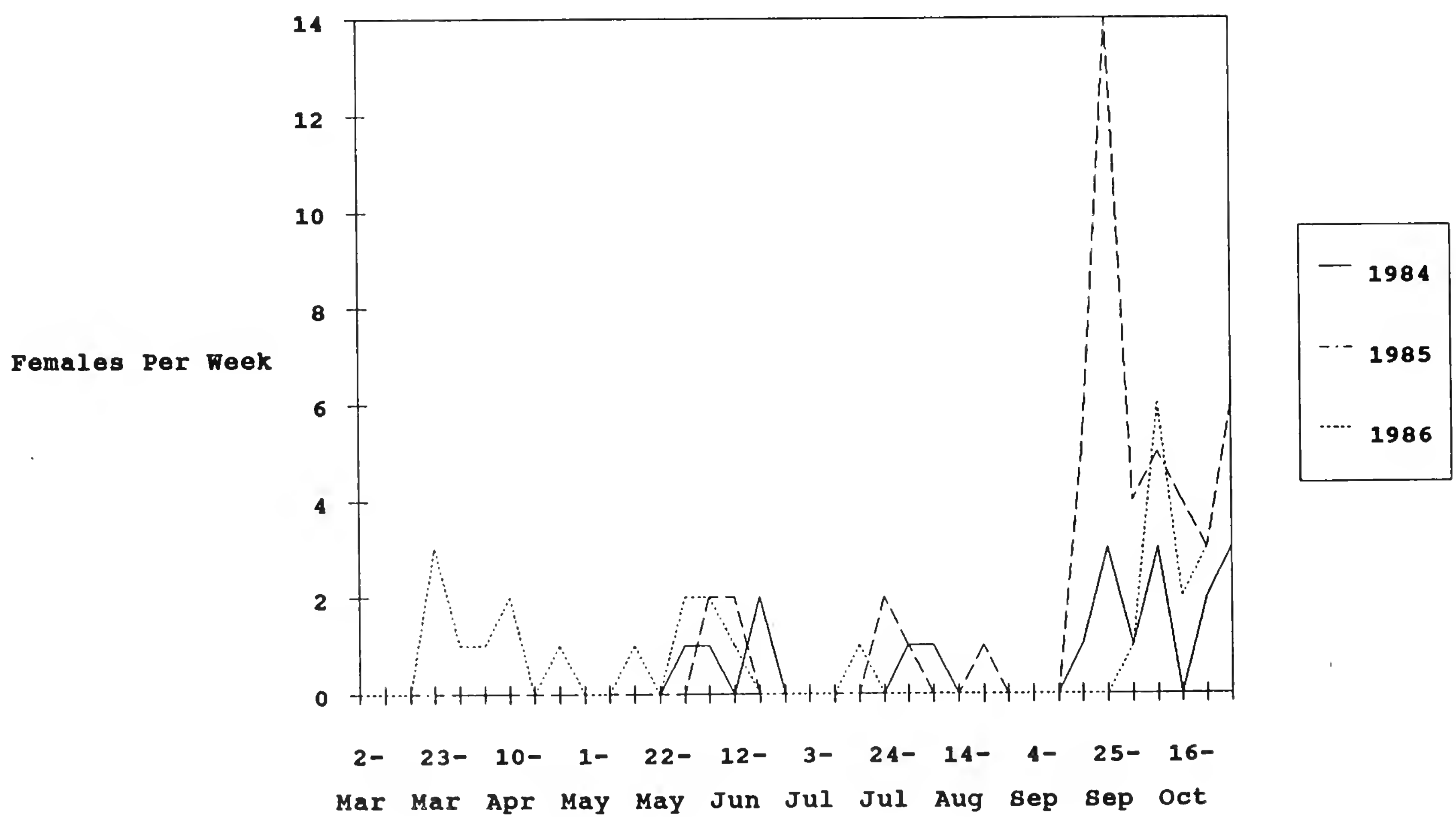
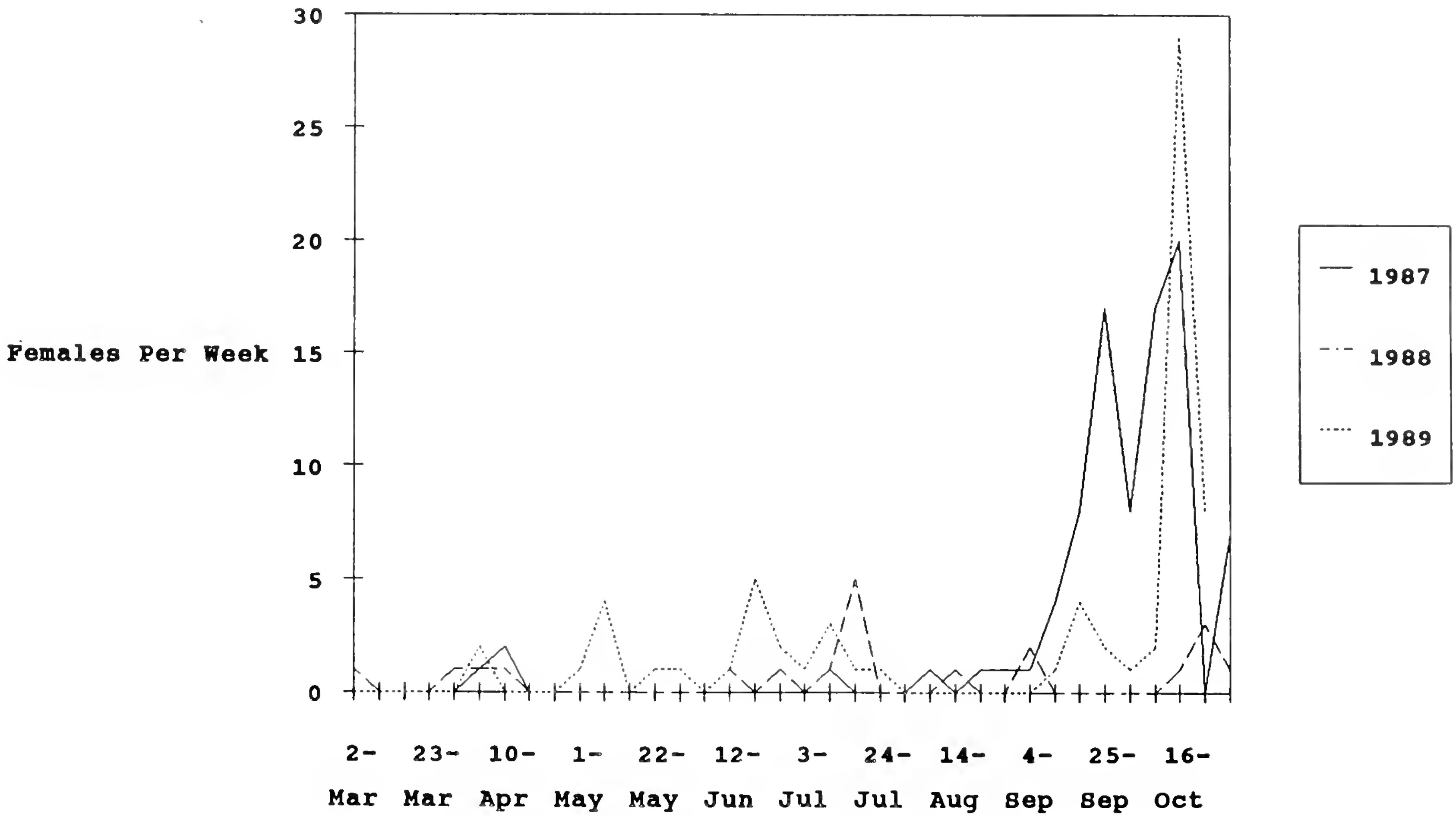
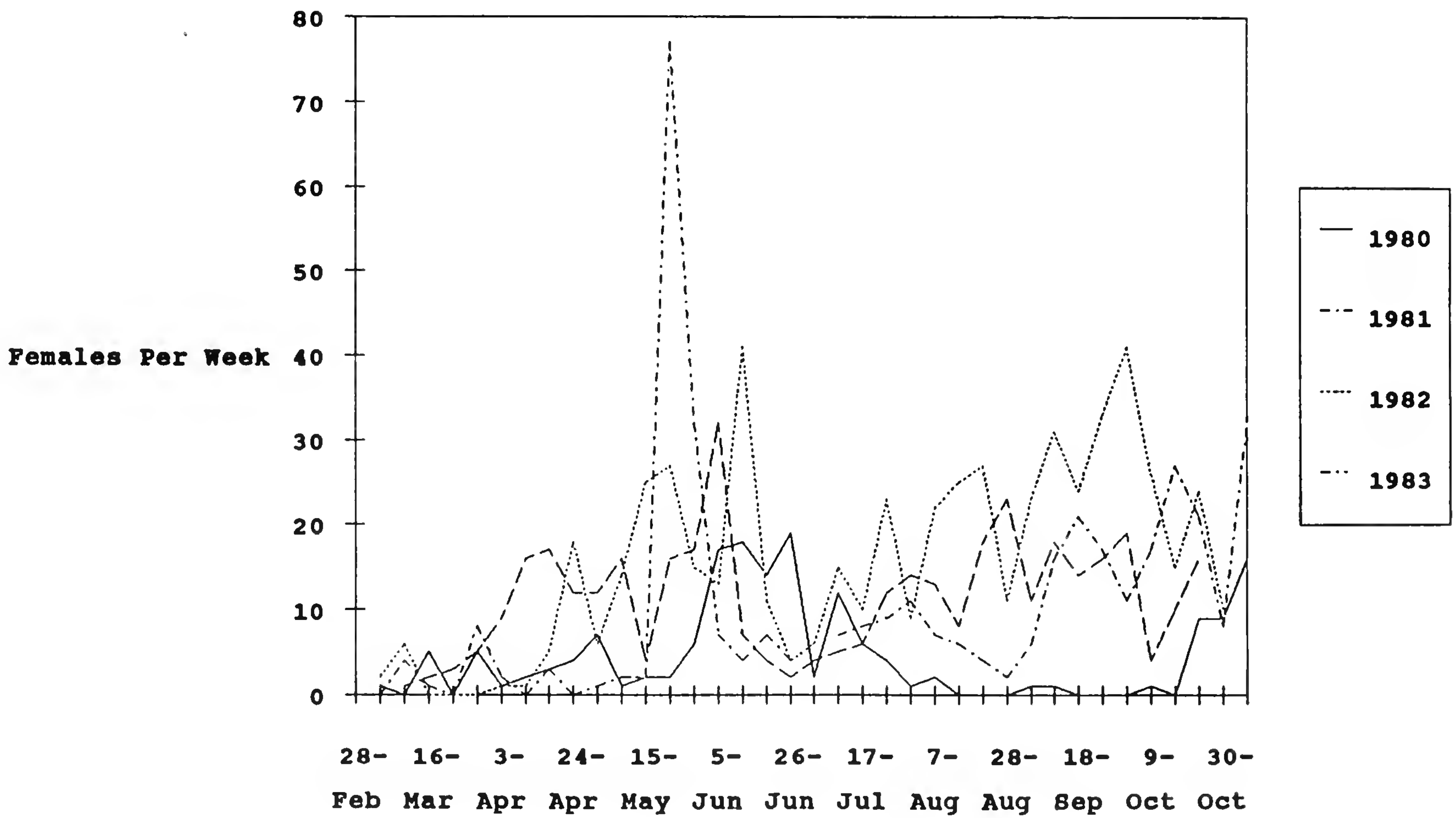
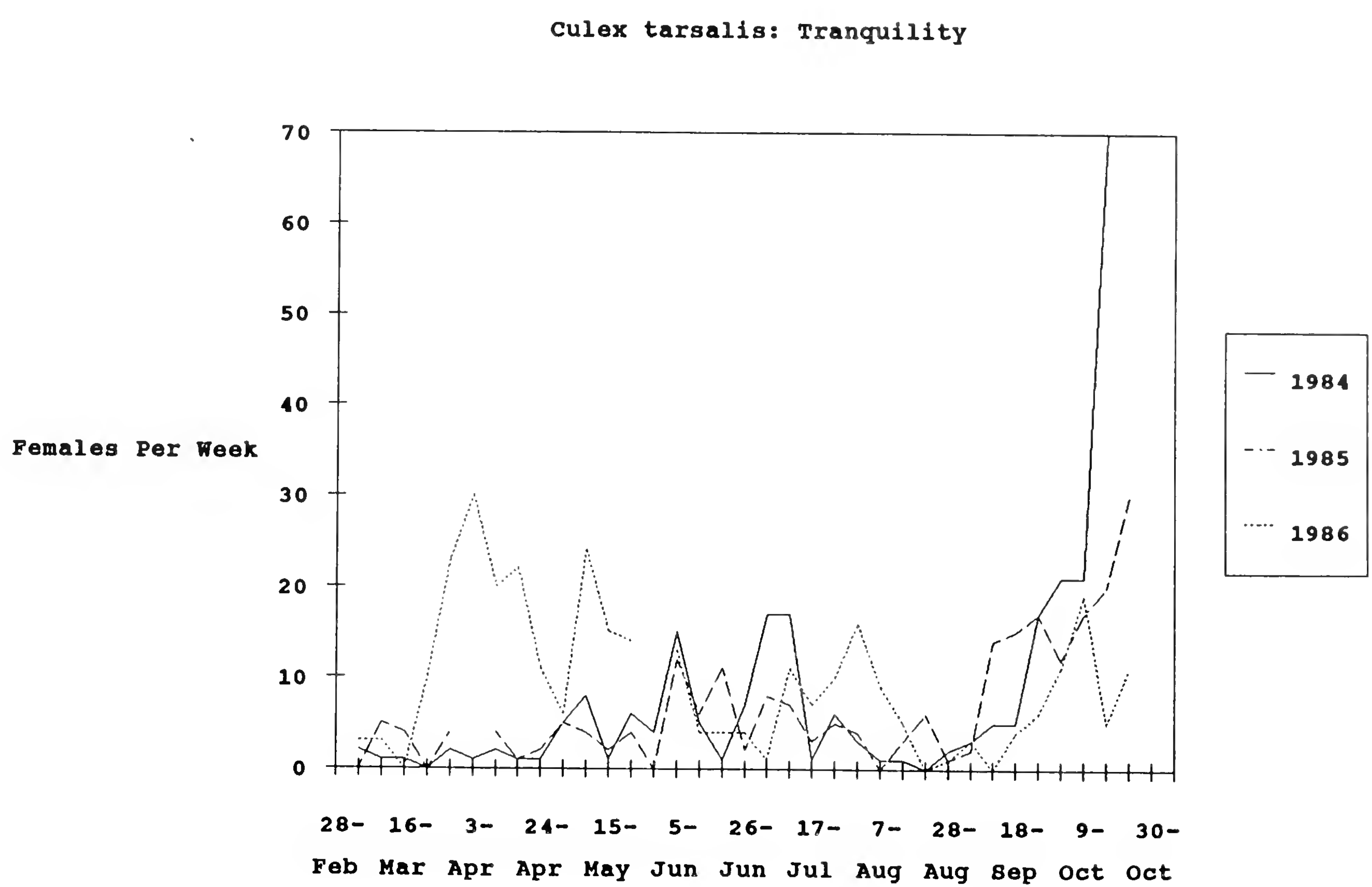


Aedes melanimon: Mendota



Culex tarsalis: Tranquility




Culex tarsalis: Tranquility
Females Per Week
70
60
50
40
30
20
10
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
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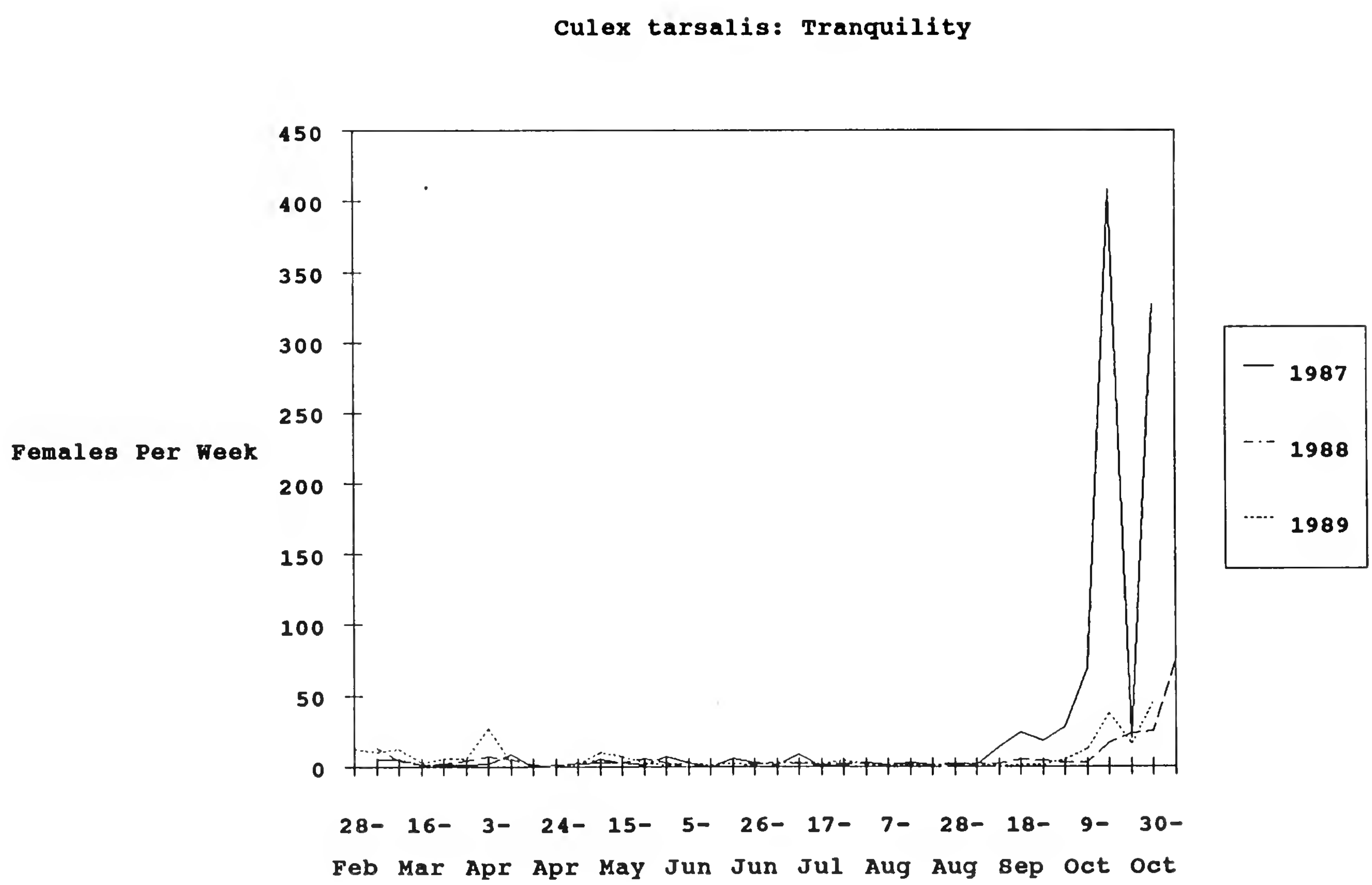
9- Oct
30- Oct
1984
1985
1986


Culex tarsalis: Tranquility
Females Per Week
450
400
350
300
250
200
150
100
50
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
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7- Aug
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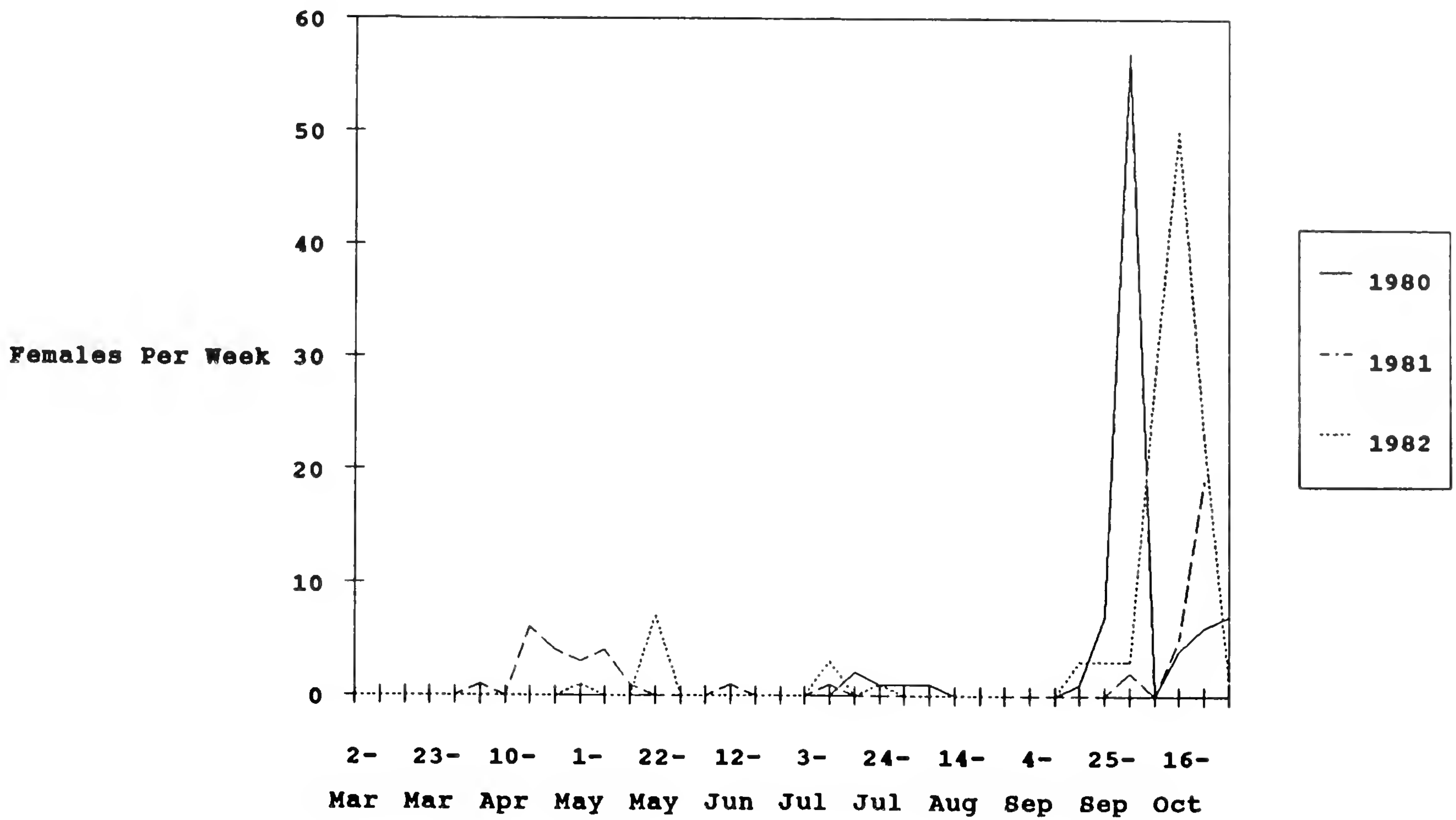
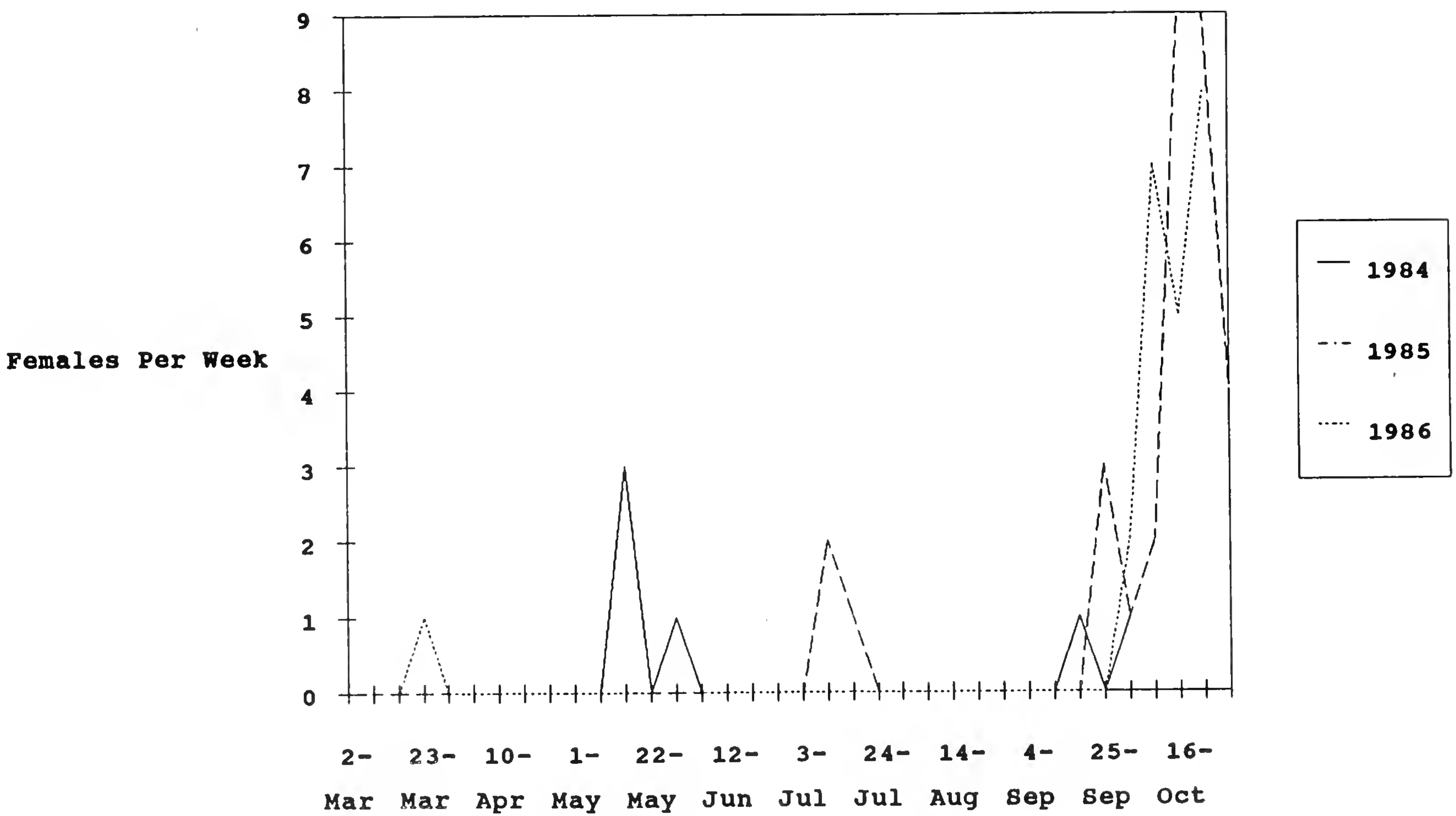
9- Oct
30- Oct
1987
1988
1989

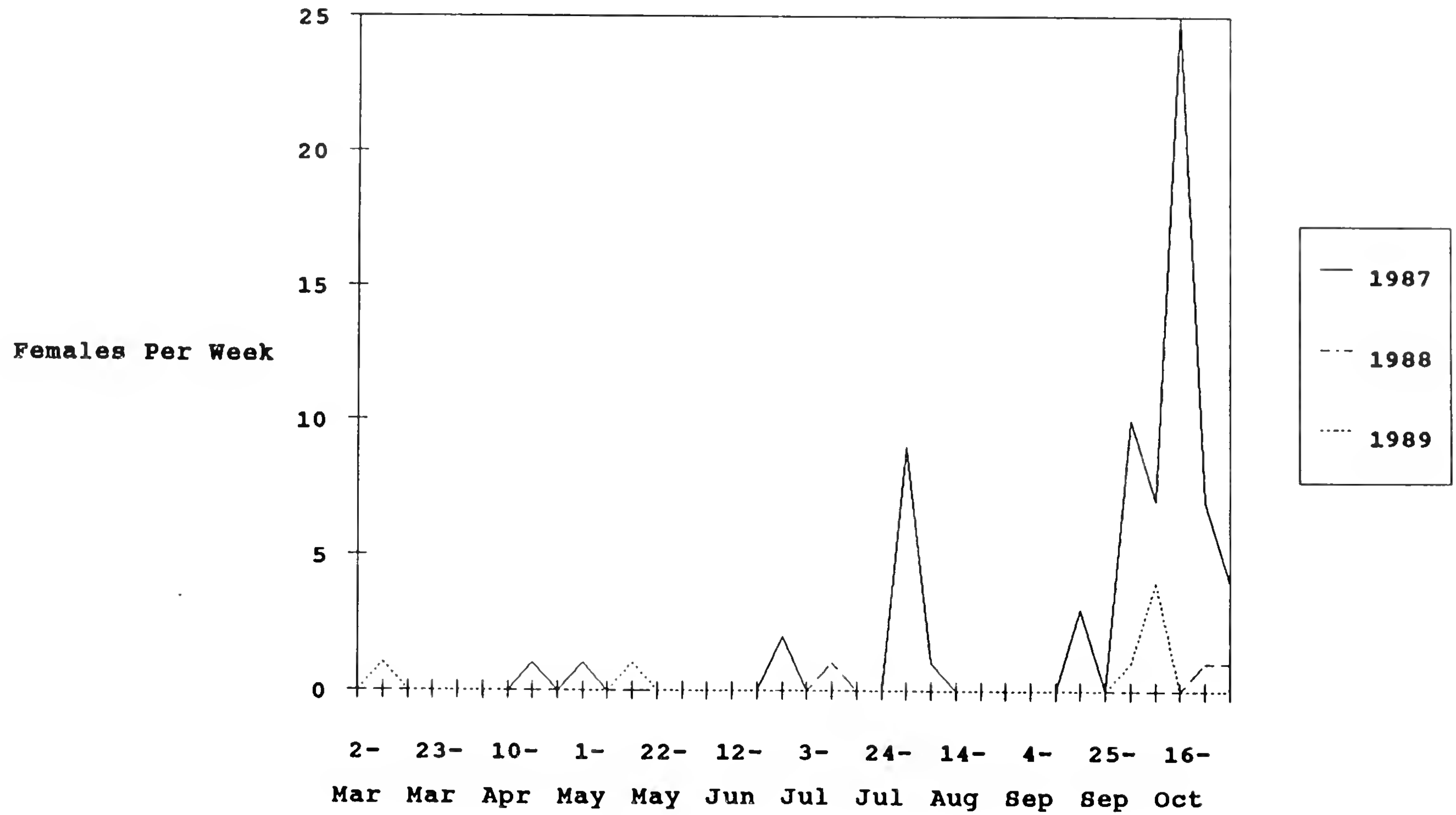
Aedes melanimon: Canuta

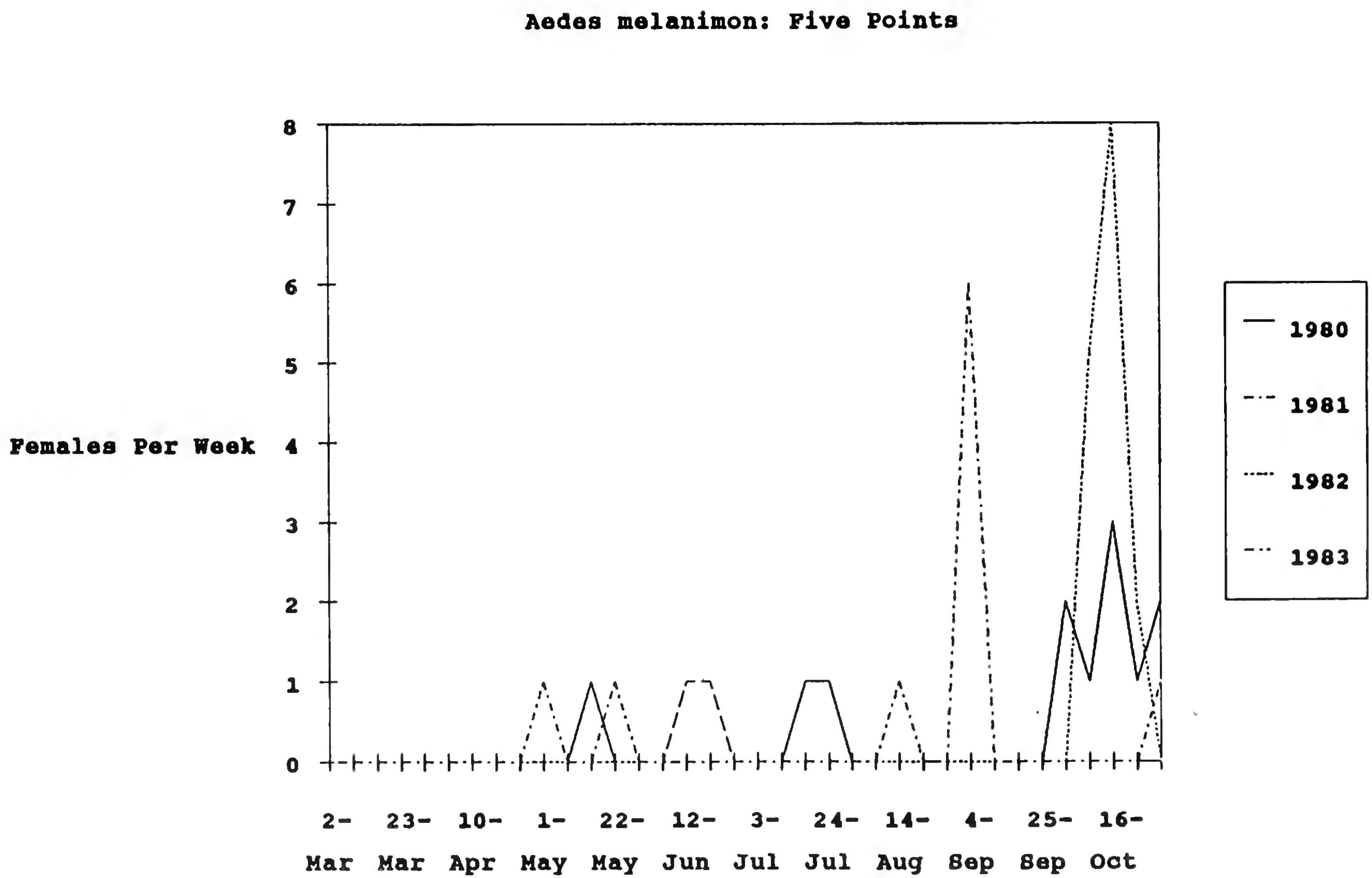


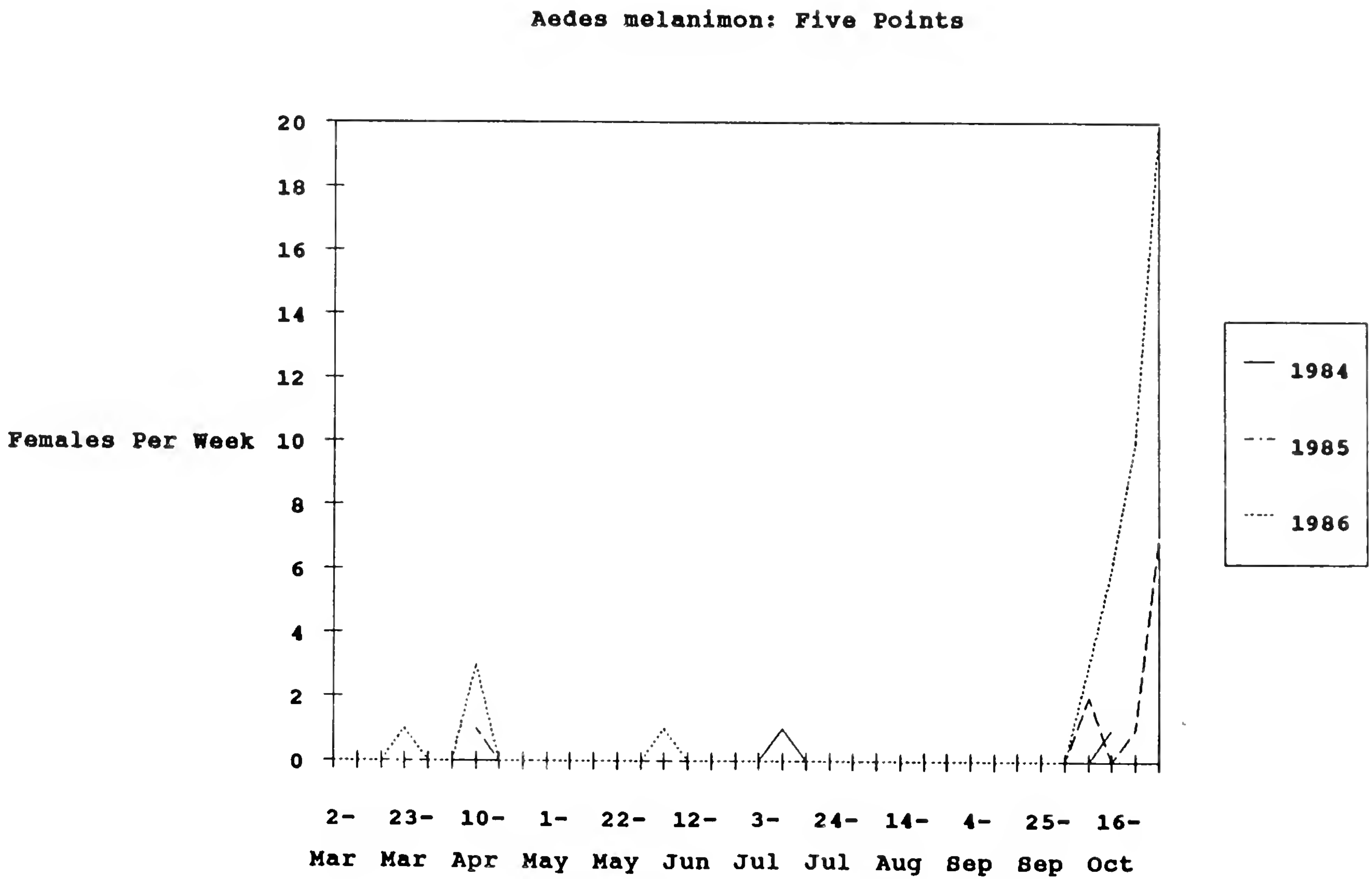
Aedes melanimon: Canuta

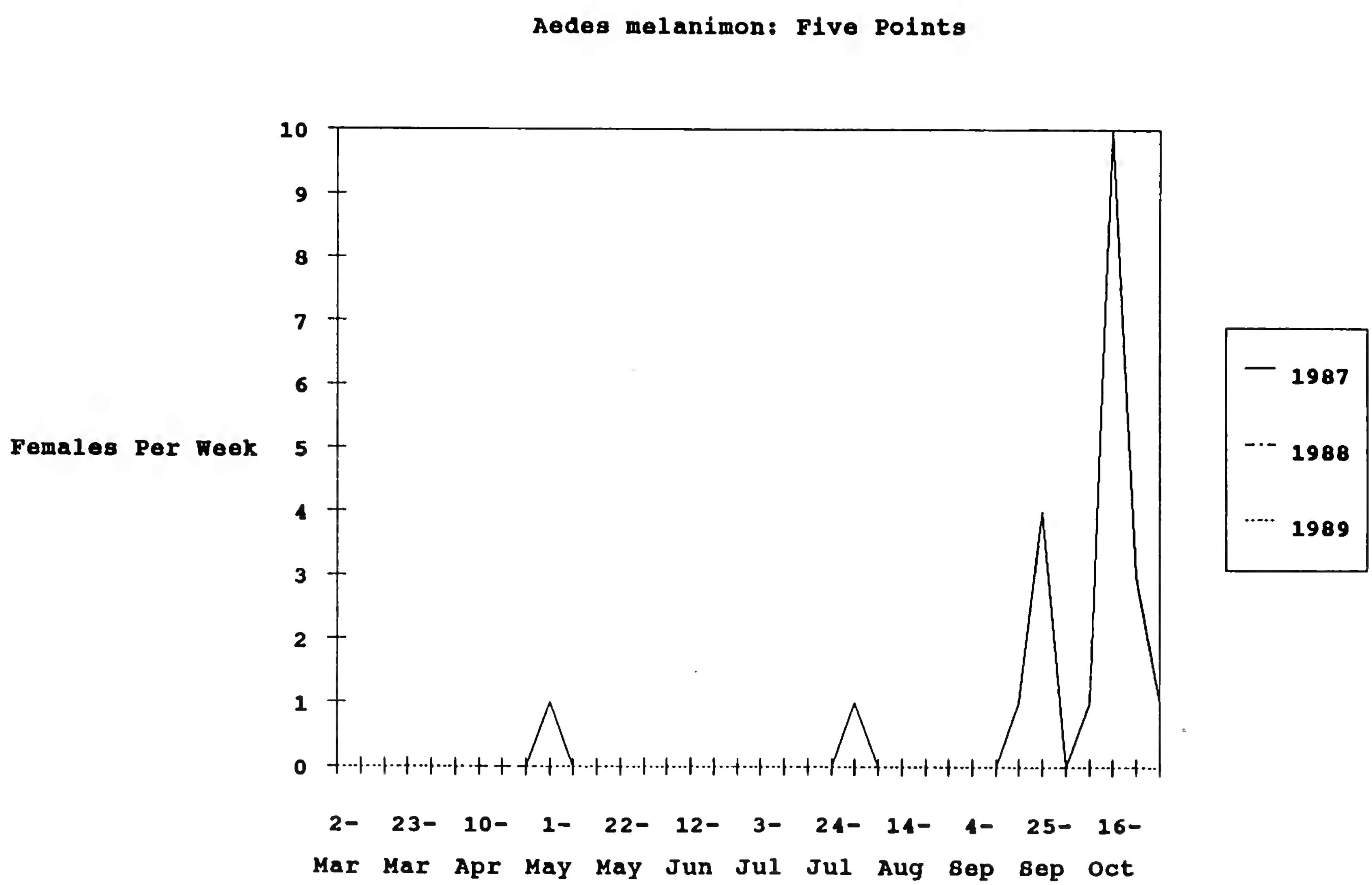


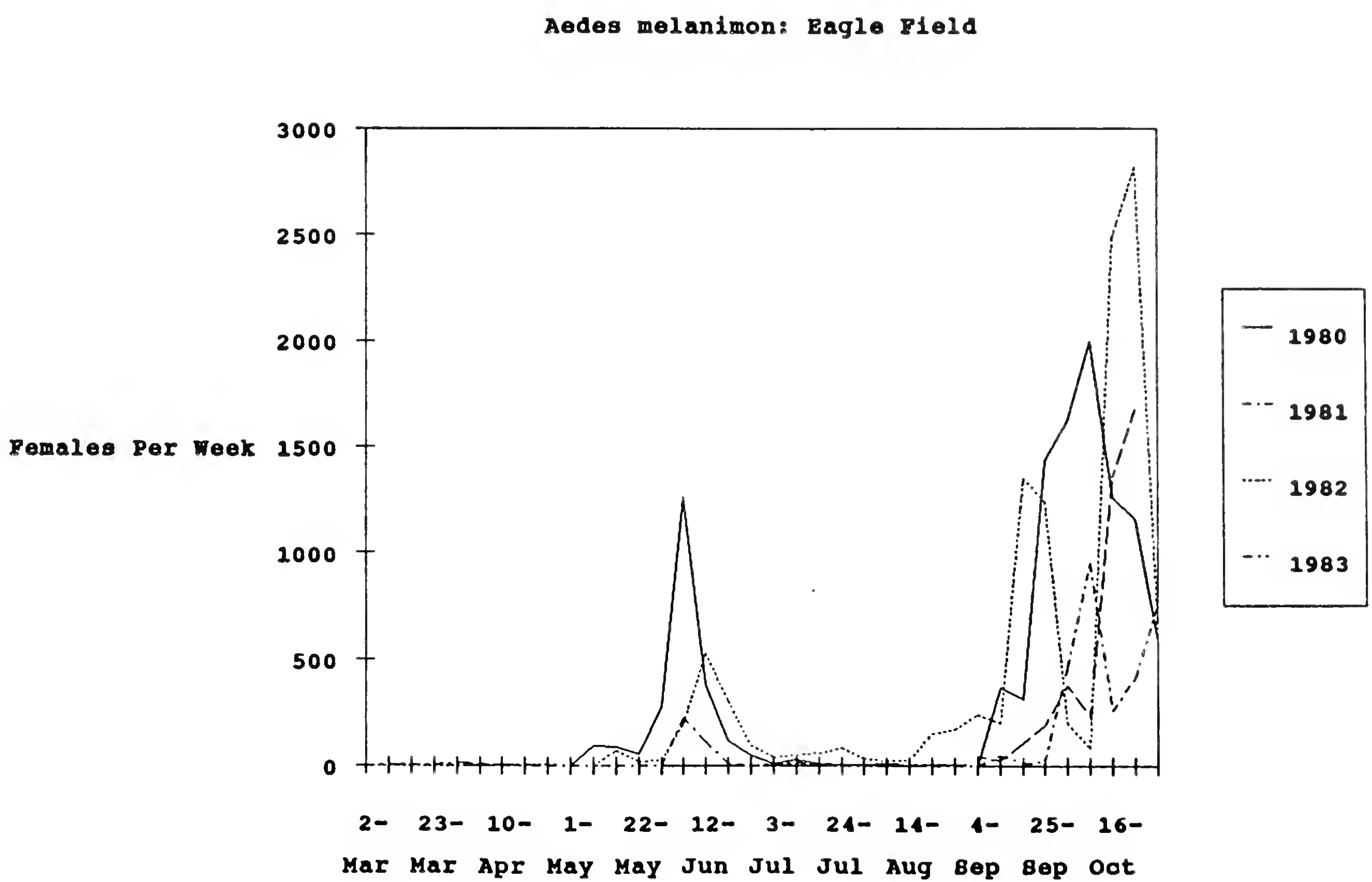
Aedes melanimon: Canuta

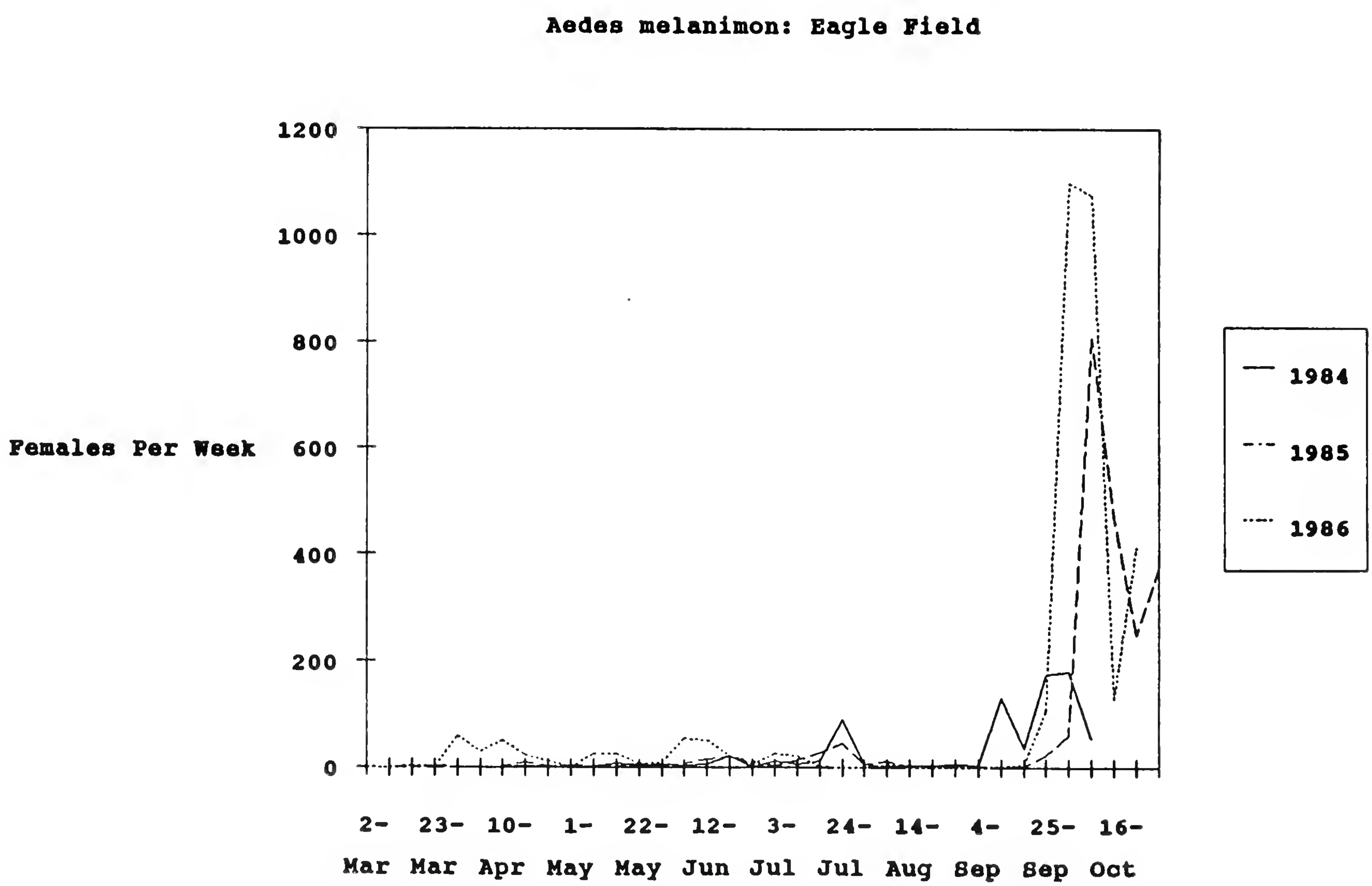



Aedes melanimon: Five Points
Females Per Week
8
7
6
5
4
3
2
1
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1980
1981
1982
1983


Aedes melanimon: Five Points
Females Per Week
20
18
16
14
12
10
8
6
4
2
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1984
1985
1986

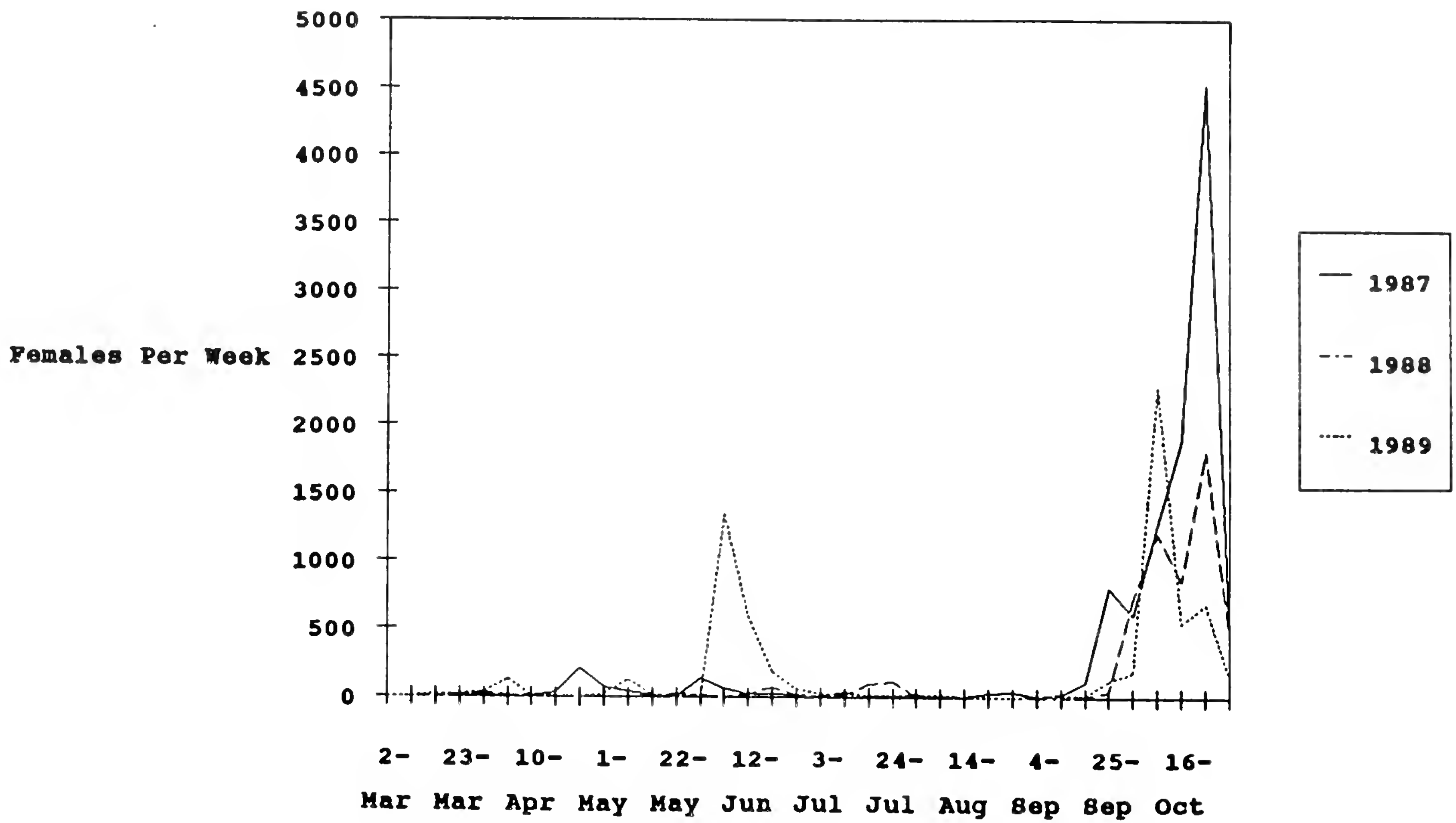

Aedes melanimon: Five Points
Females Per Week
10
9
8
7
6
5
4
3
2
1
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1987
1988
1989


Aedes melanimon: Eagle Field
Females Per Week
3000
2500
2000
1500
1000
500
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1980
1981
1982
1983

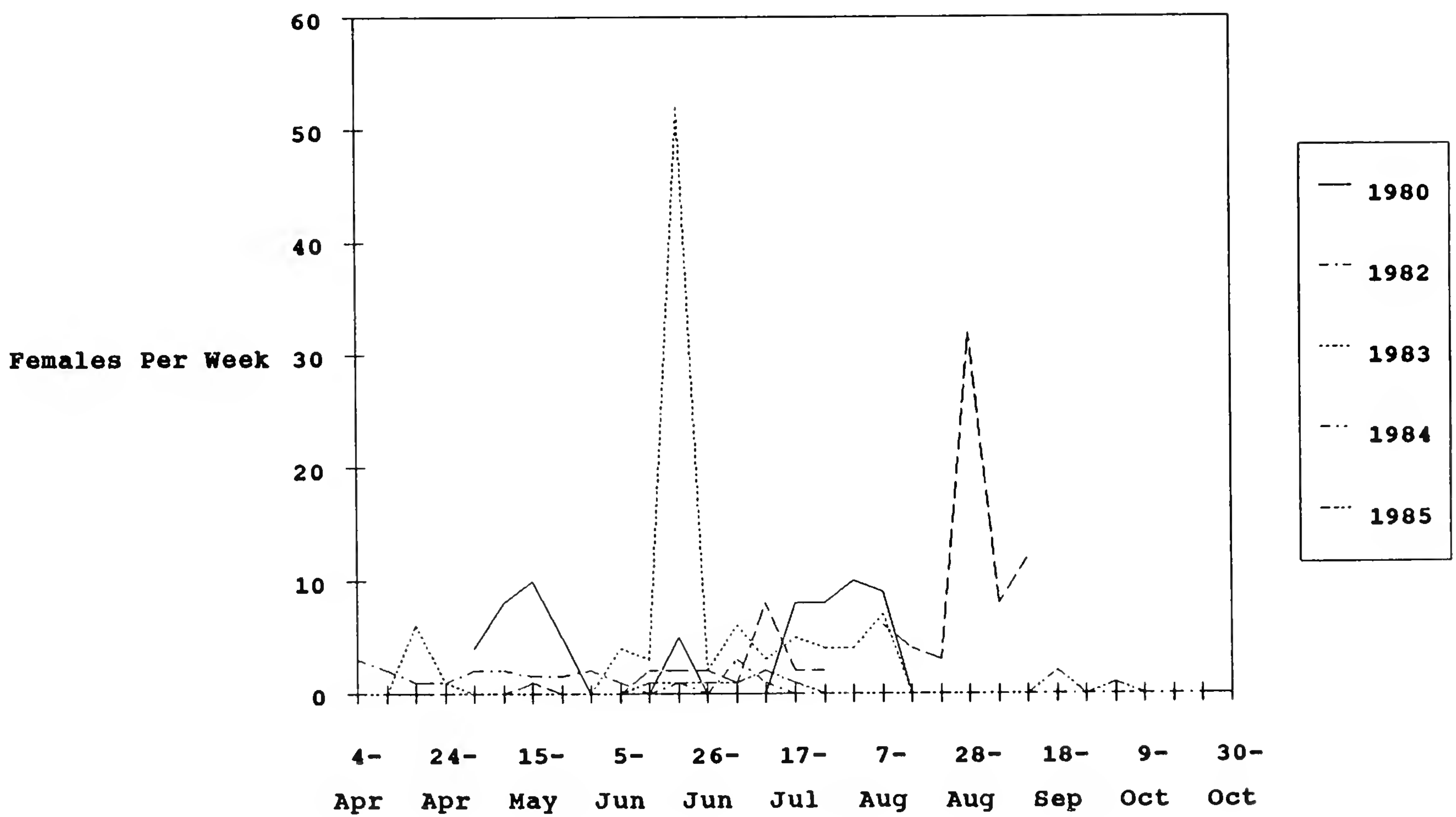


Aedes melanimon: Eagle Field
Females Per Week
1200
1000
800
600
400
200
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1984
1985
1986

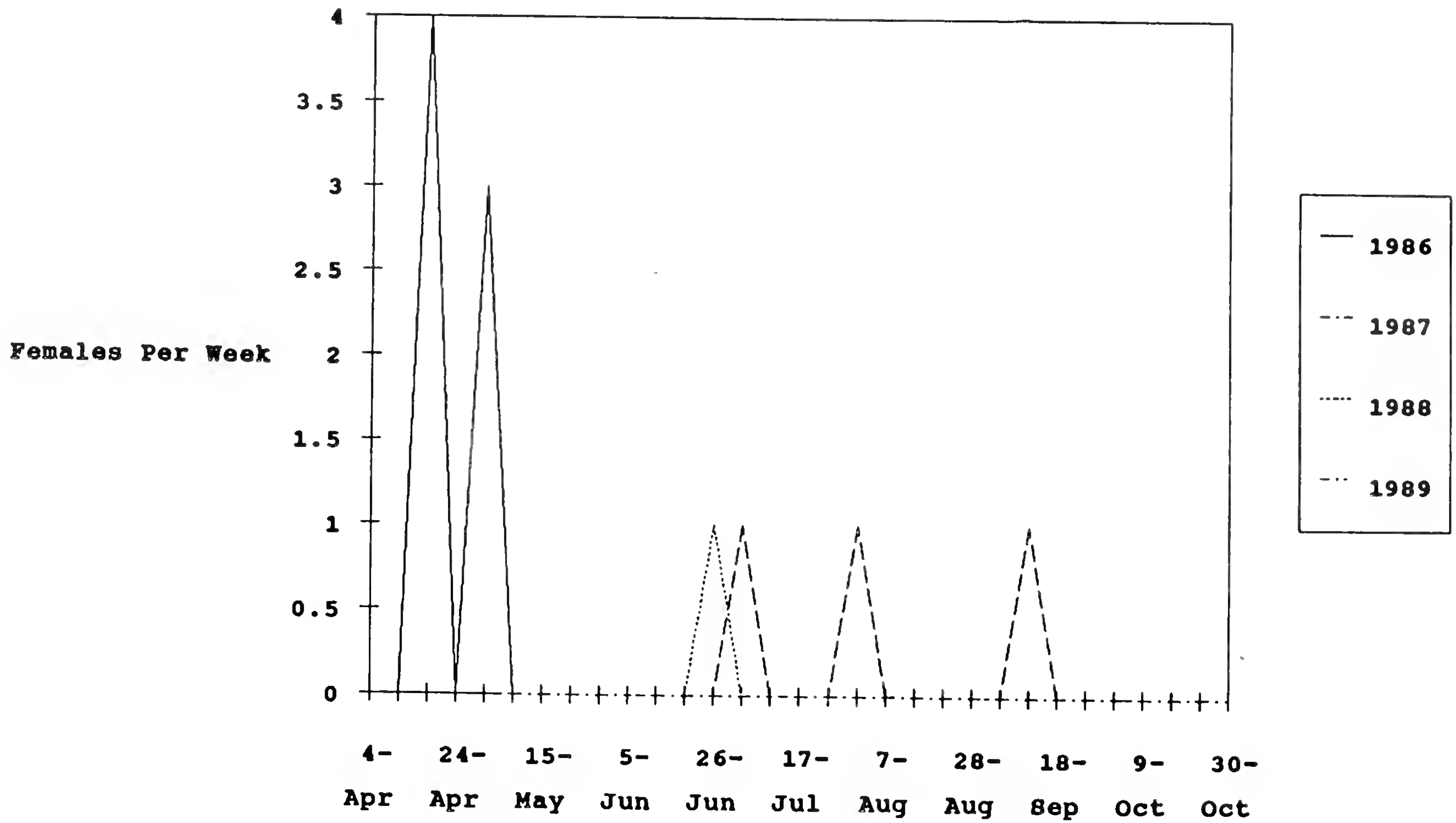
Aedes melanimon: Eagle Field



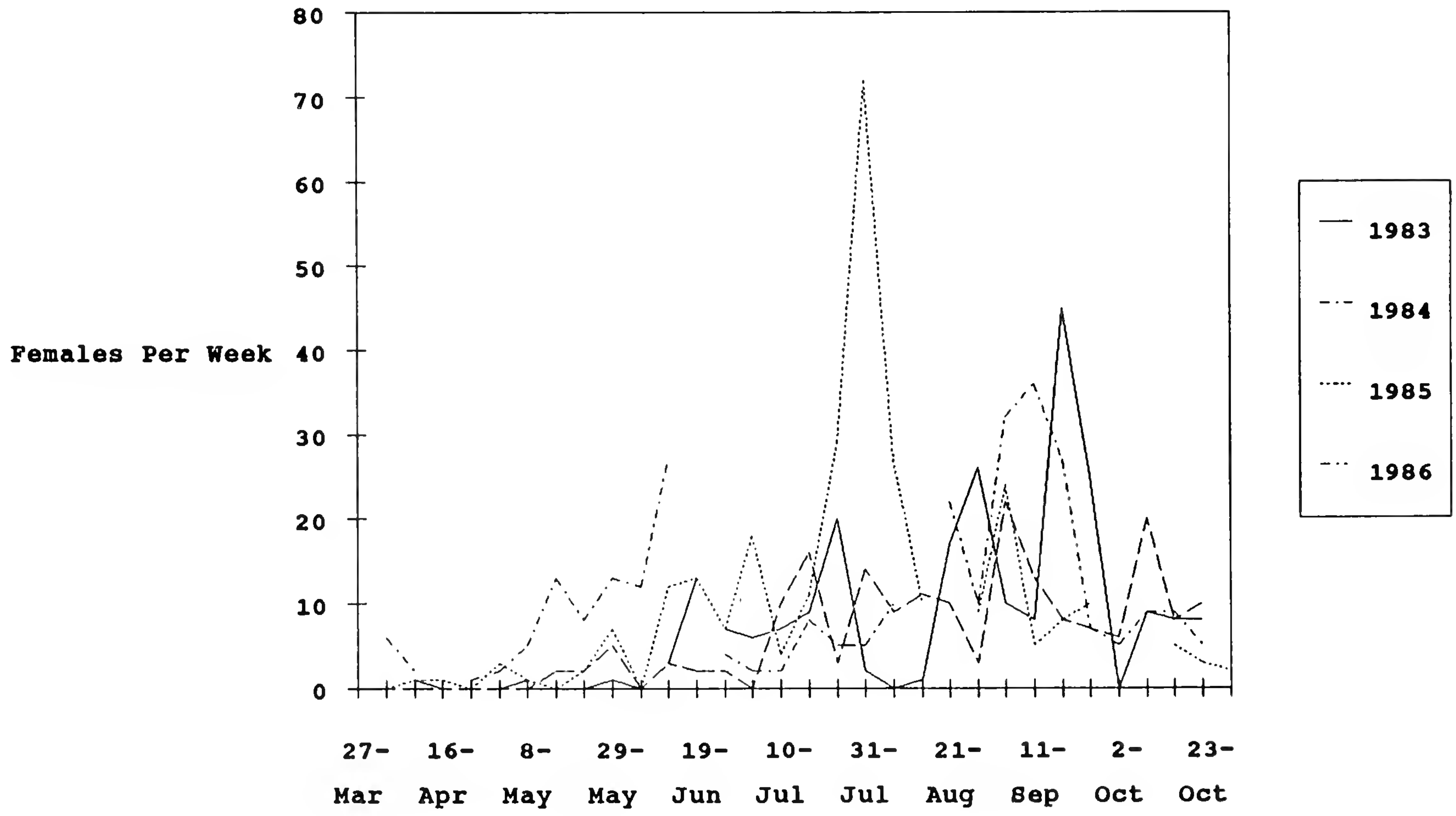
Aedes melanimon: Stratford



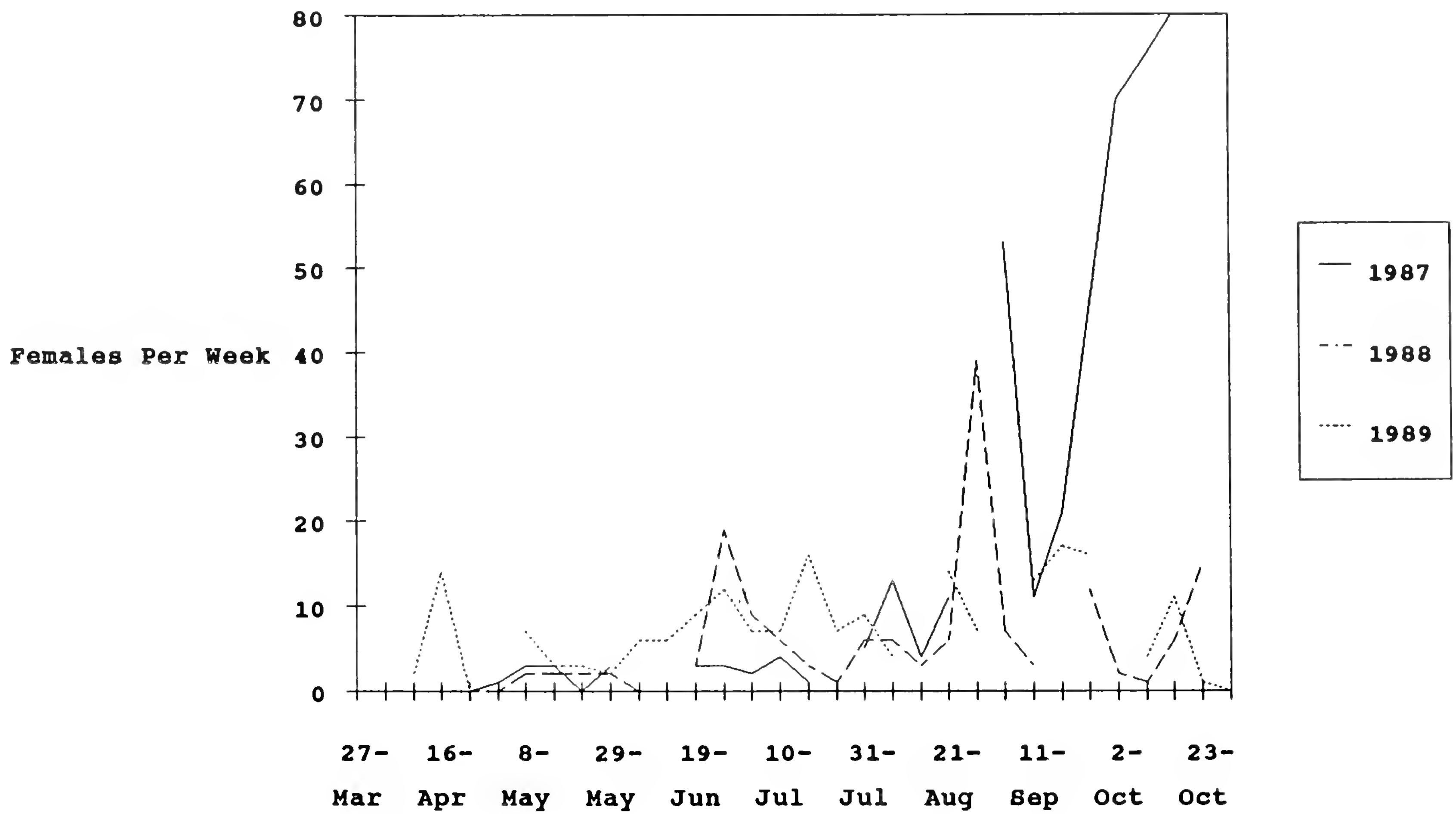
Aedes melanimon: Stratford

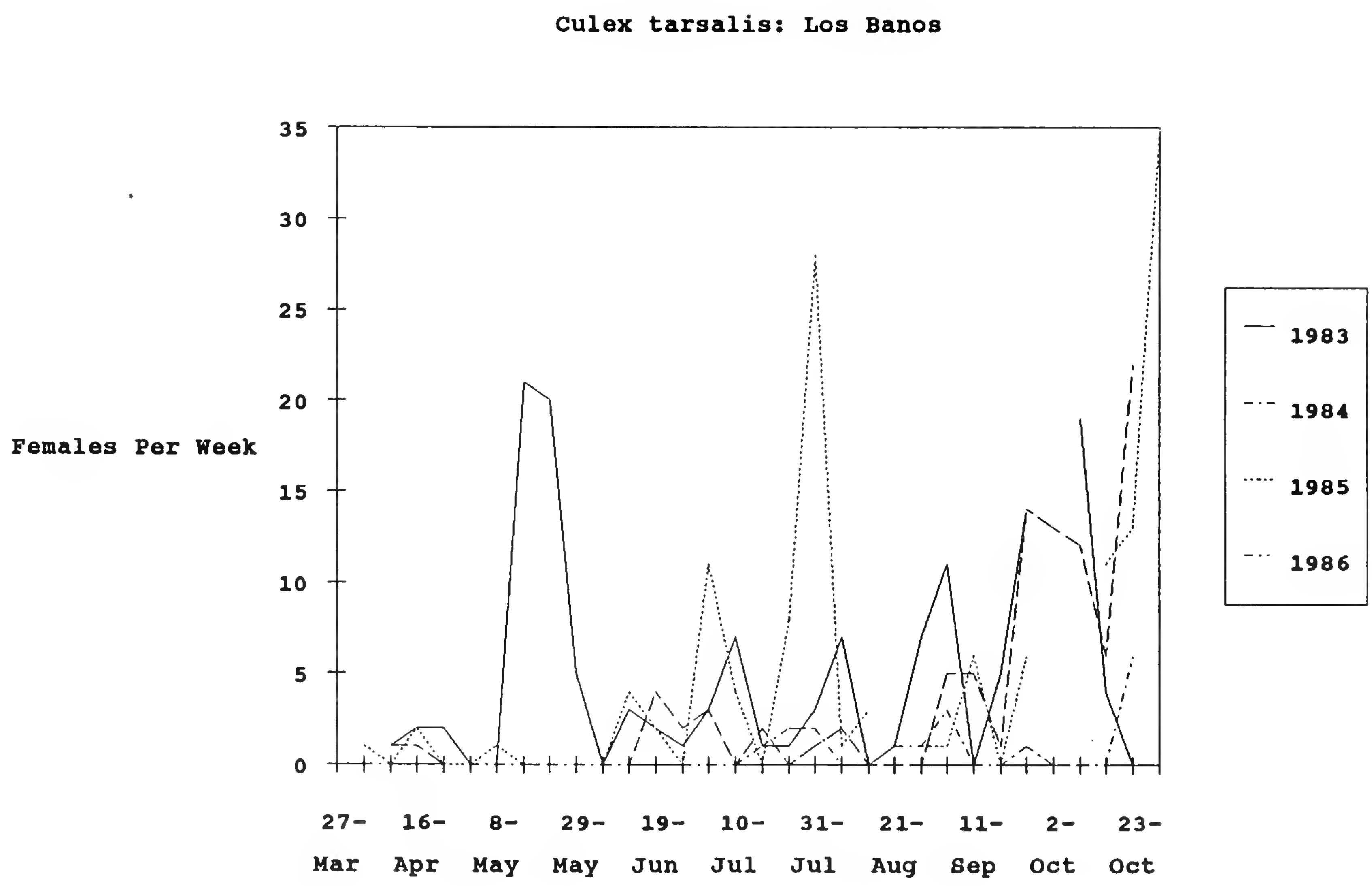


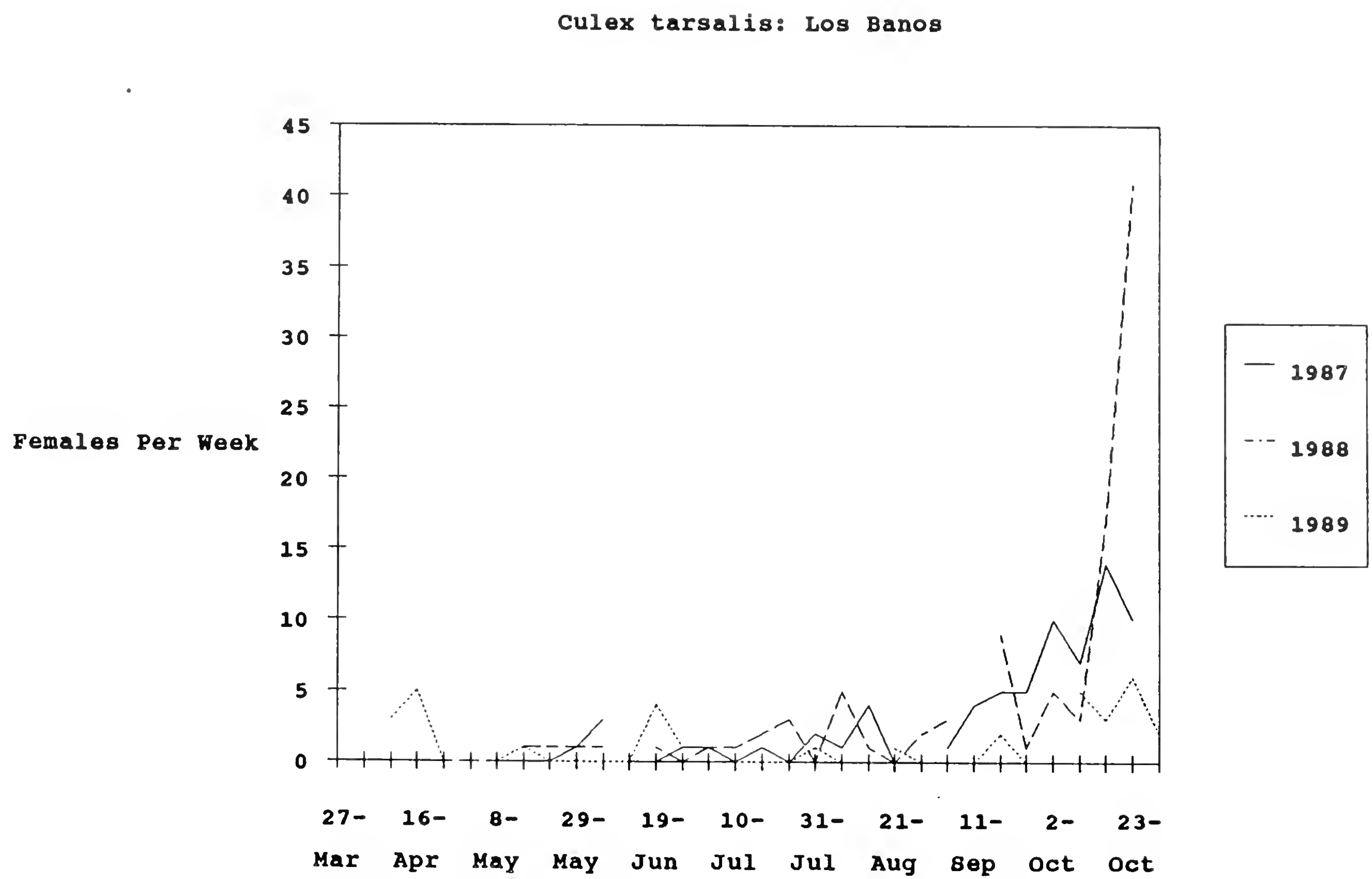
Culex tarsalis: Gustine



Culex tarsalis: Gustine

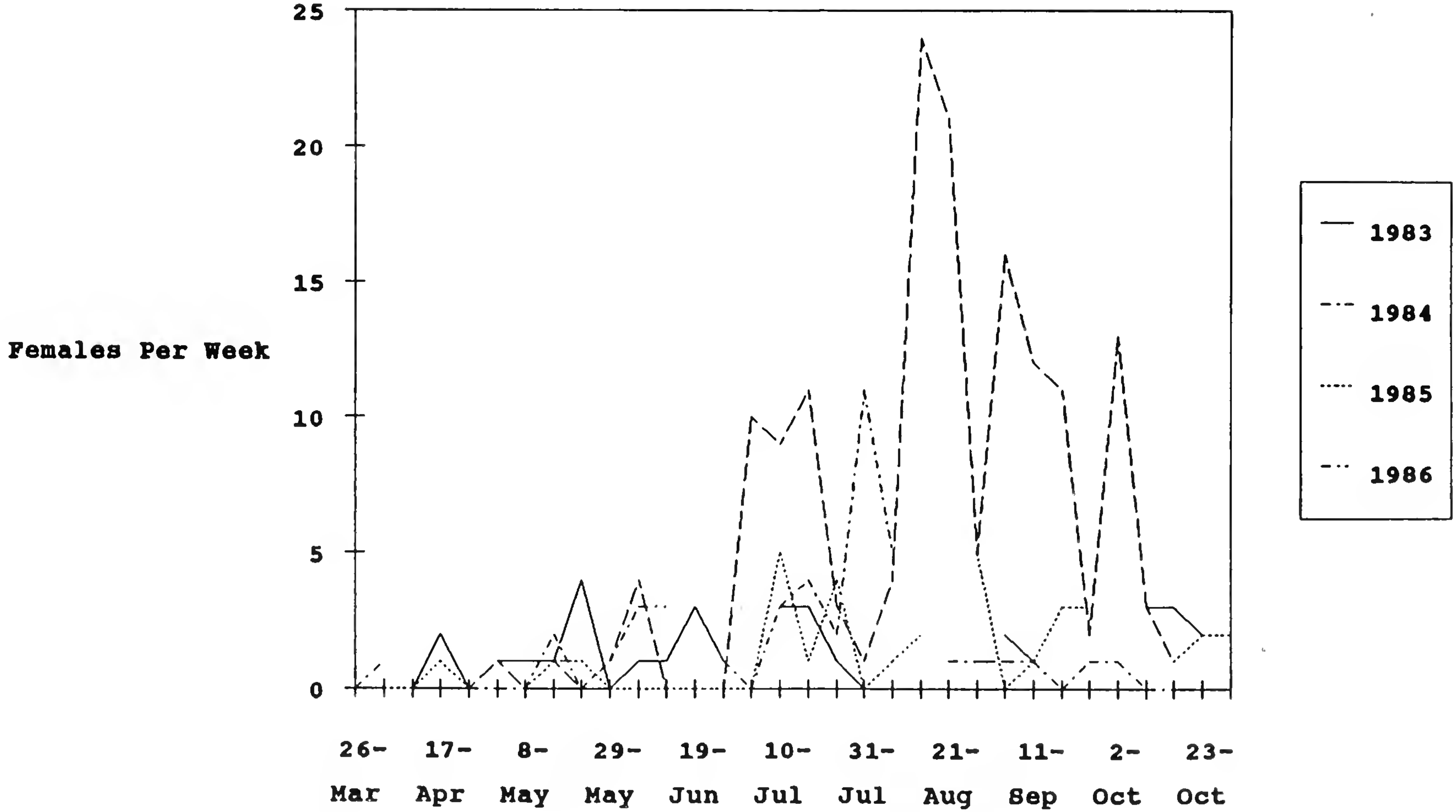



Culex tarsalis: Los Banos
Females Per Week
35
30
25
20
15
10
5
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1983
1984
1985
1986

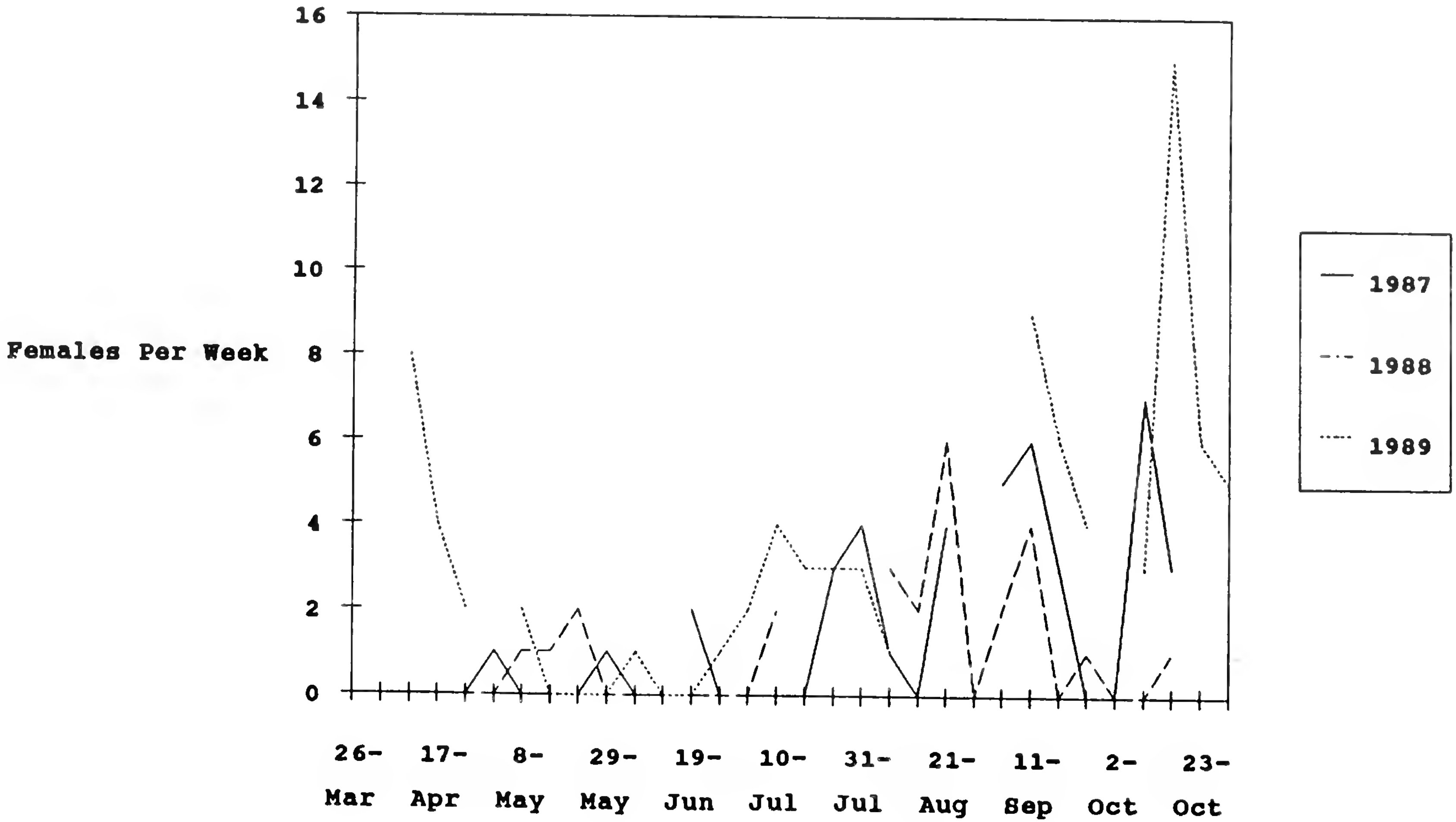


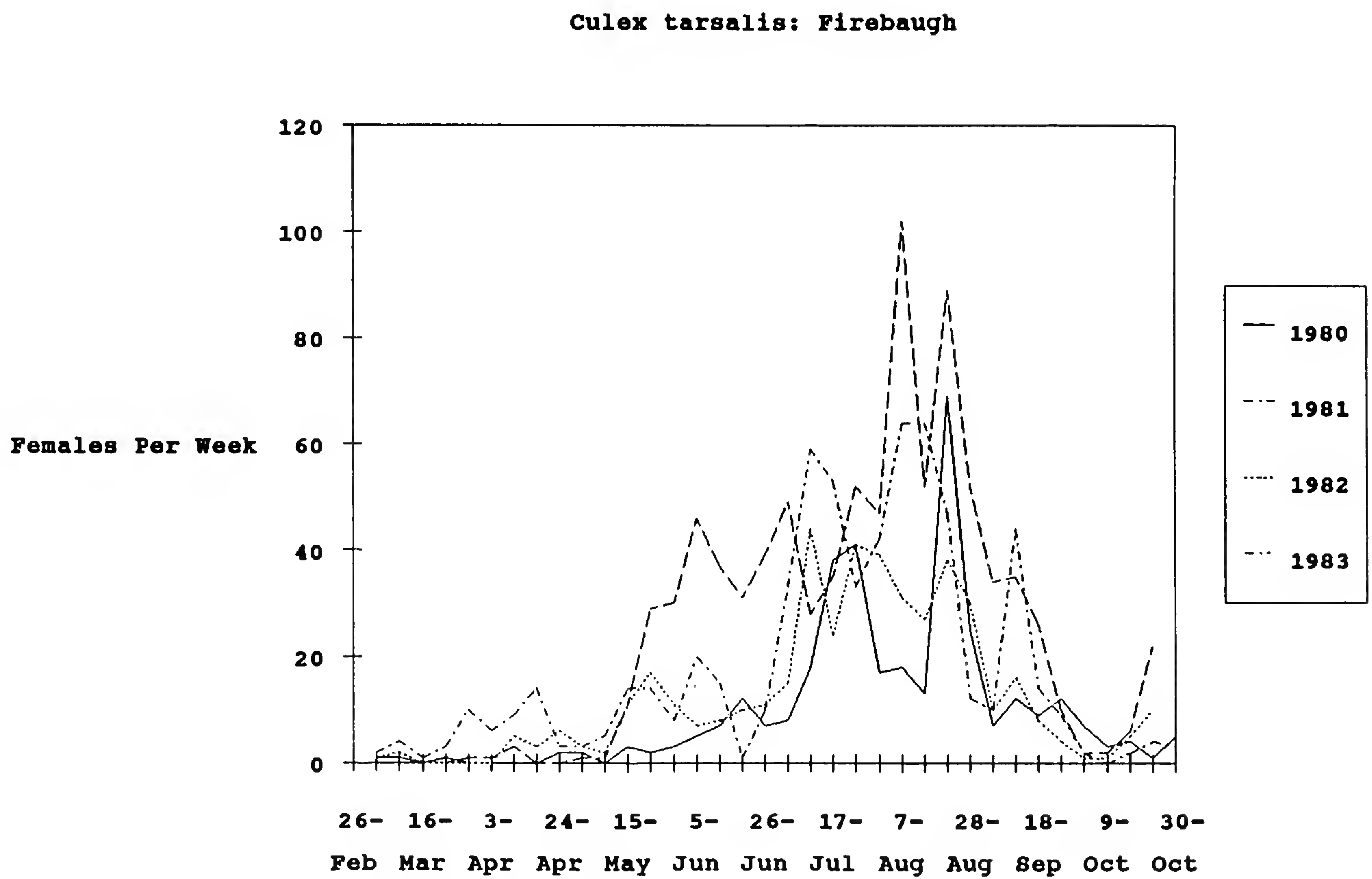
Culex tarsalis: Los Banos
Females Per Week
45
40
35
30
25
20
15
10
5
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

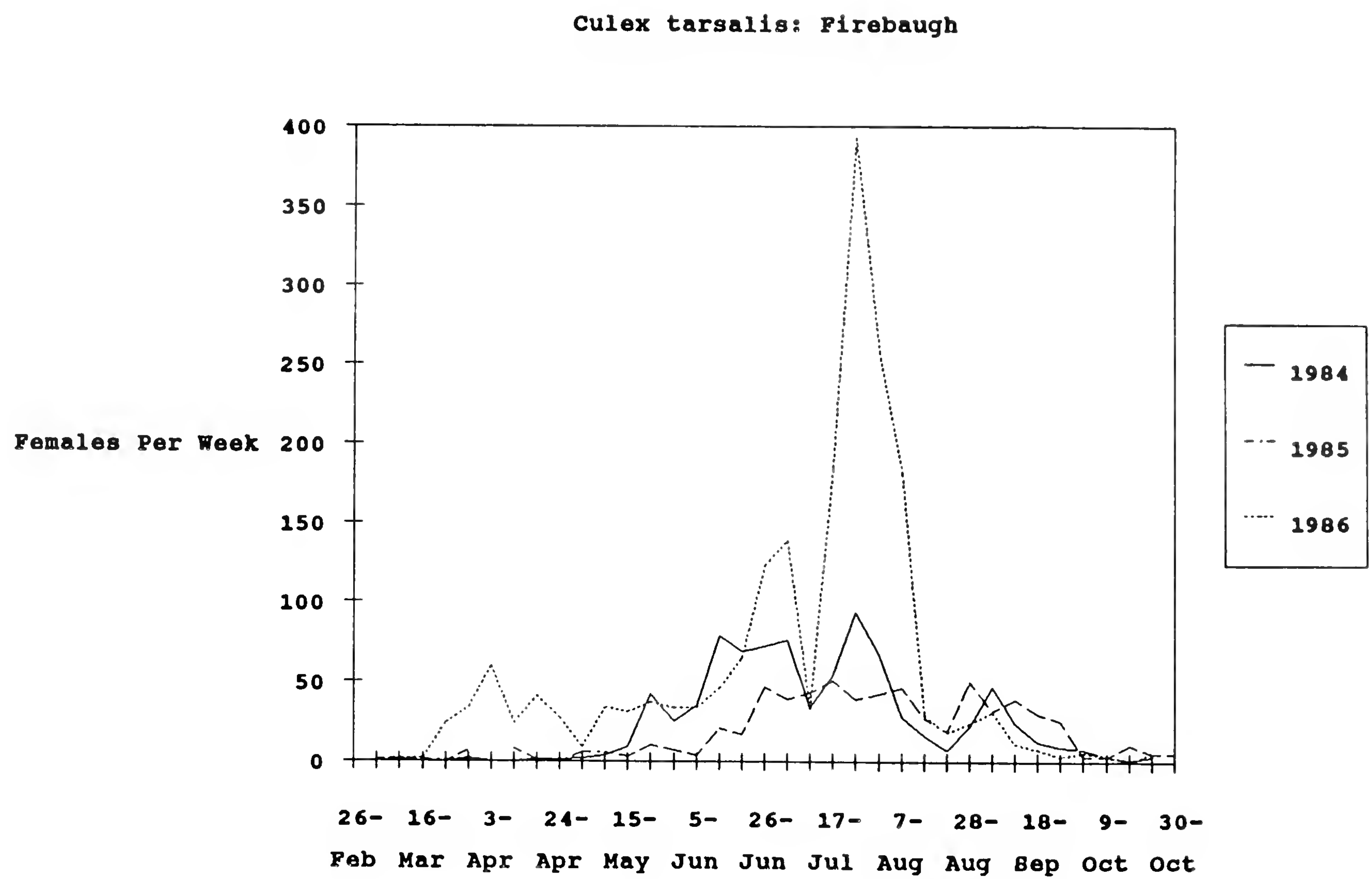
Culex tarsalis: Dos Palos



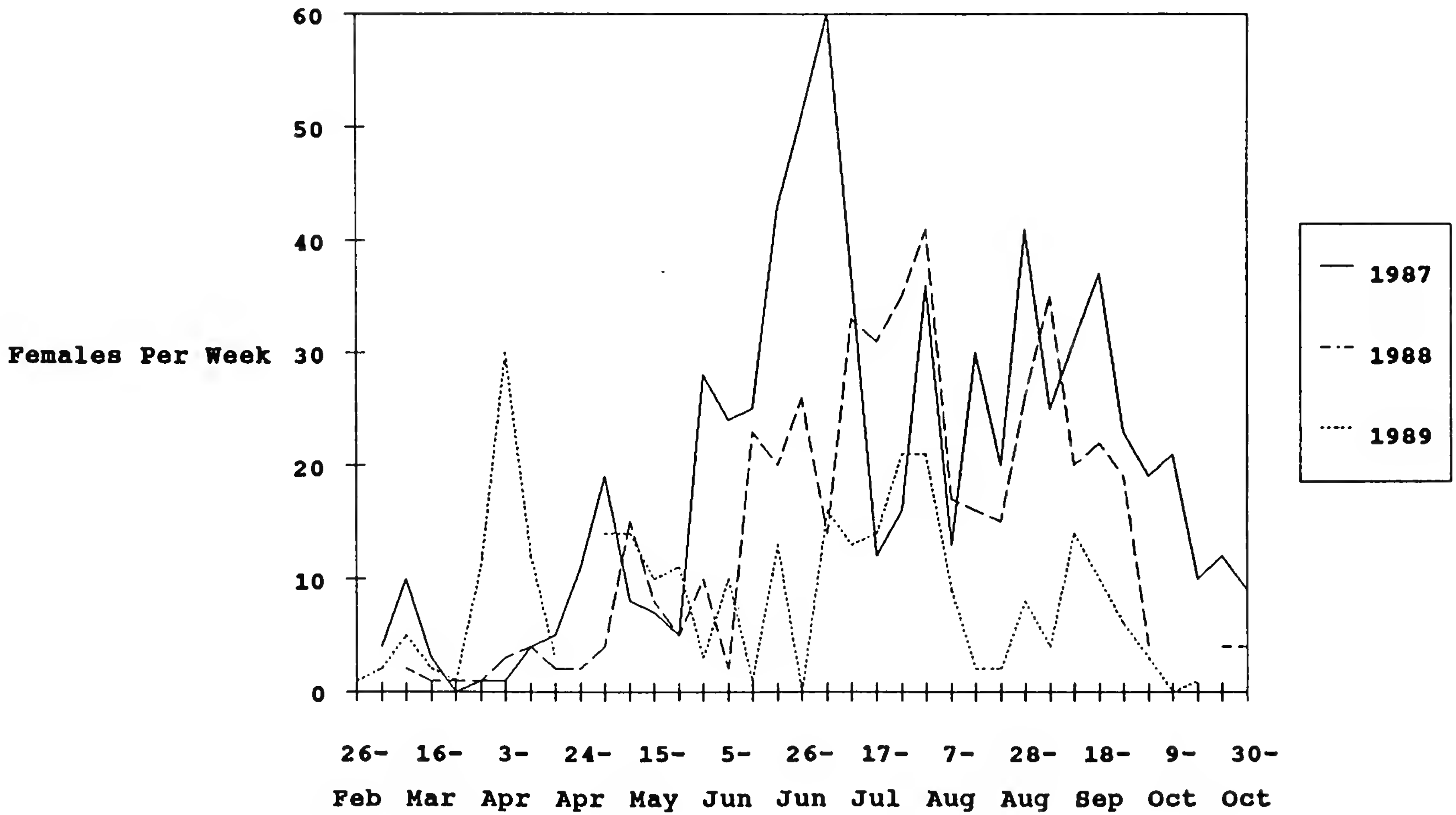
Culex tarsalis: Dos Palos



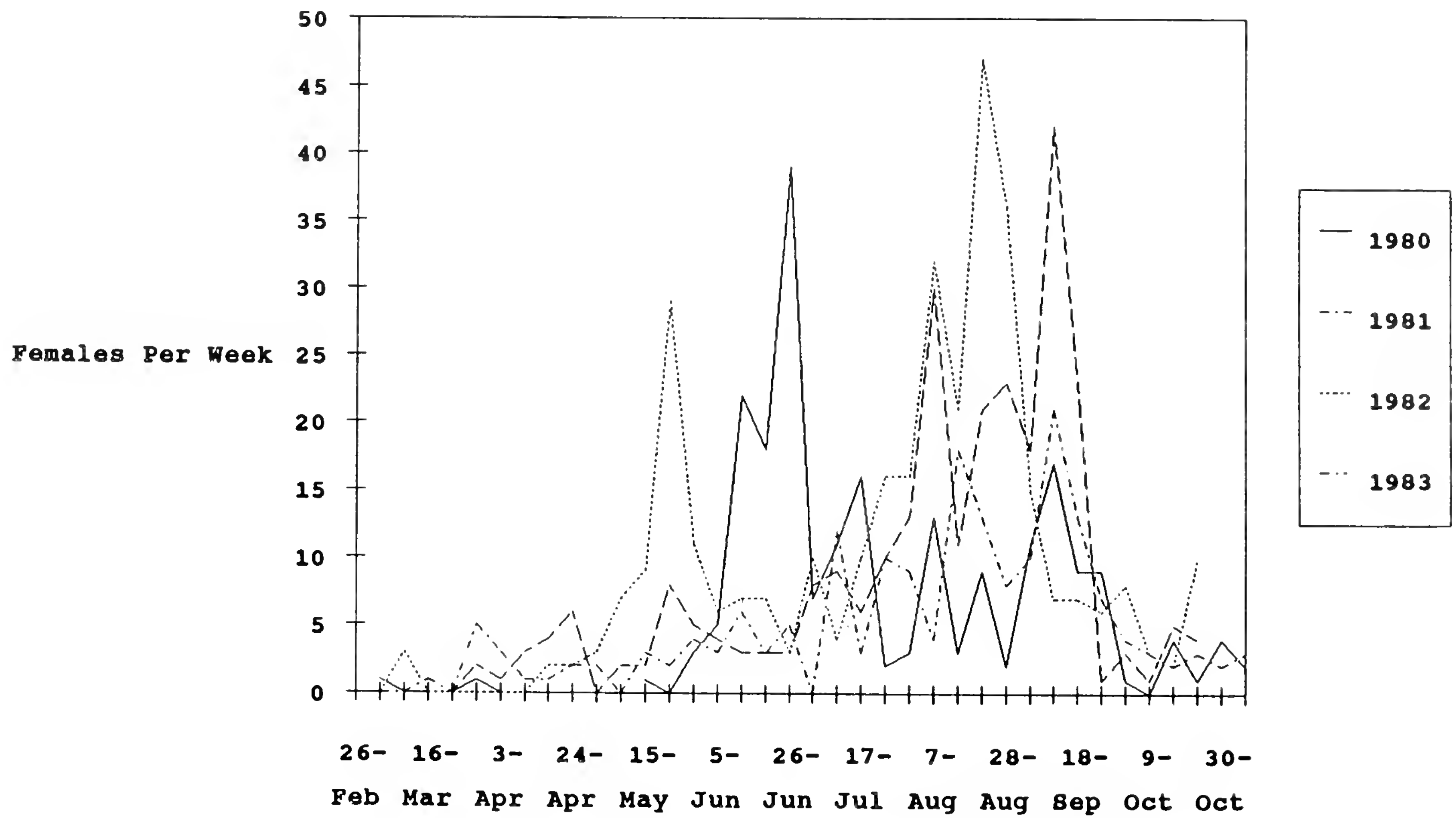

Culex tarsalis: Firebaugh
Females Per Week
120
100
80
60
40
20
0
26- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1980
1981
1982
1983

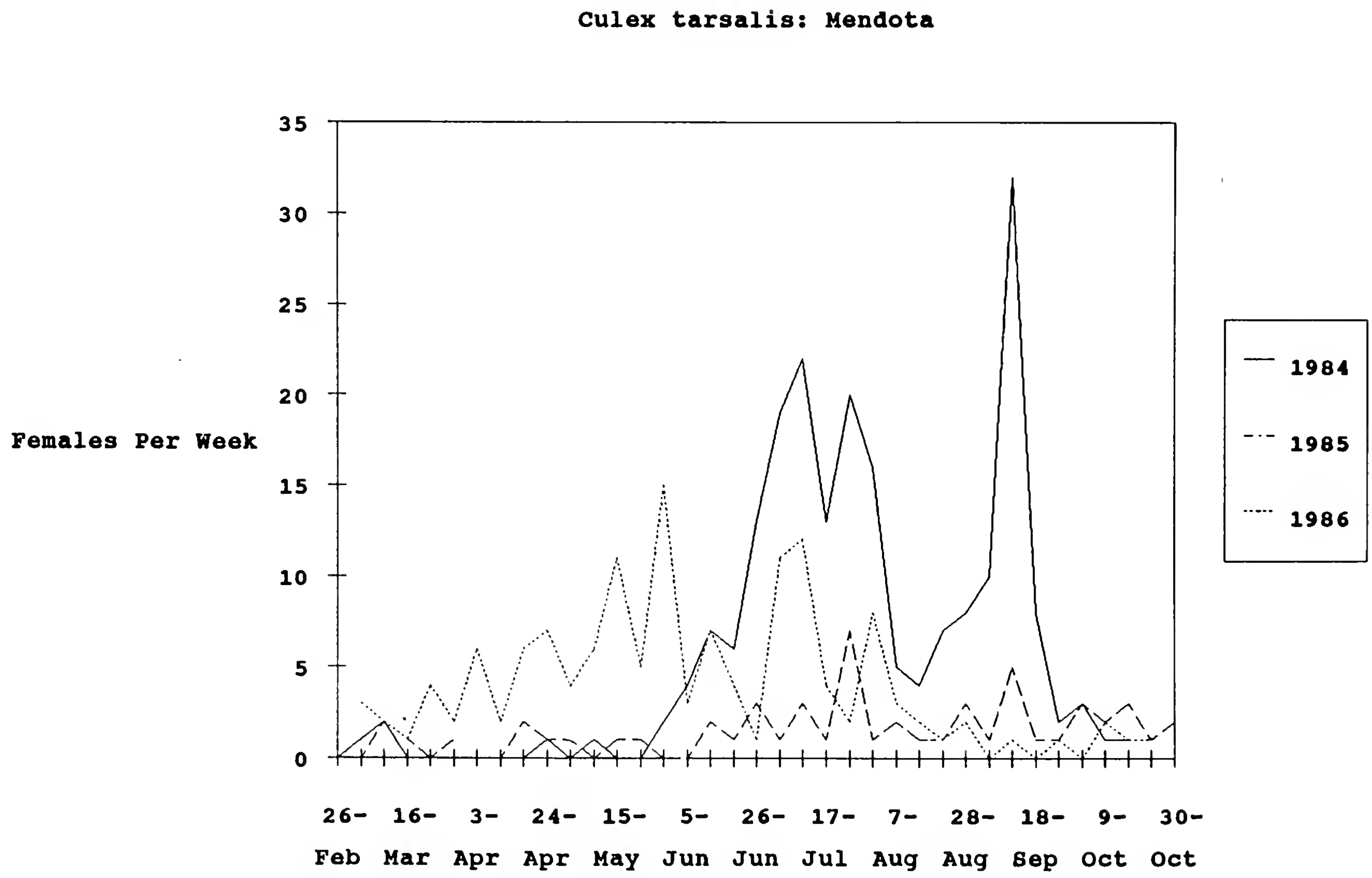

Culex tarsalis: Firebaugh
Females Per Week
400
350
300
250
200
150
100
50
0
26- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

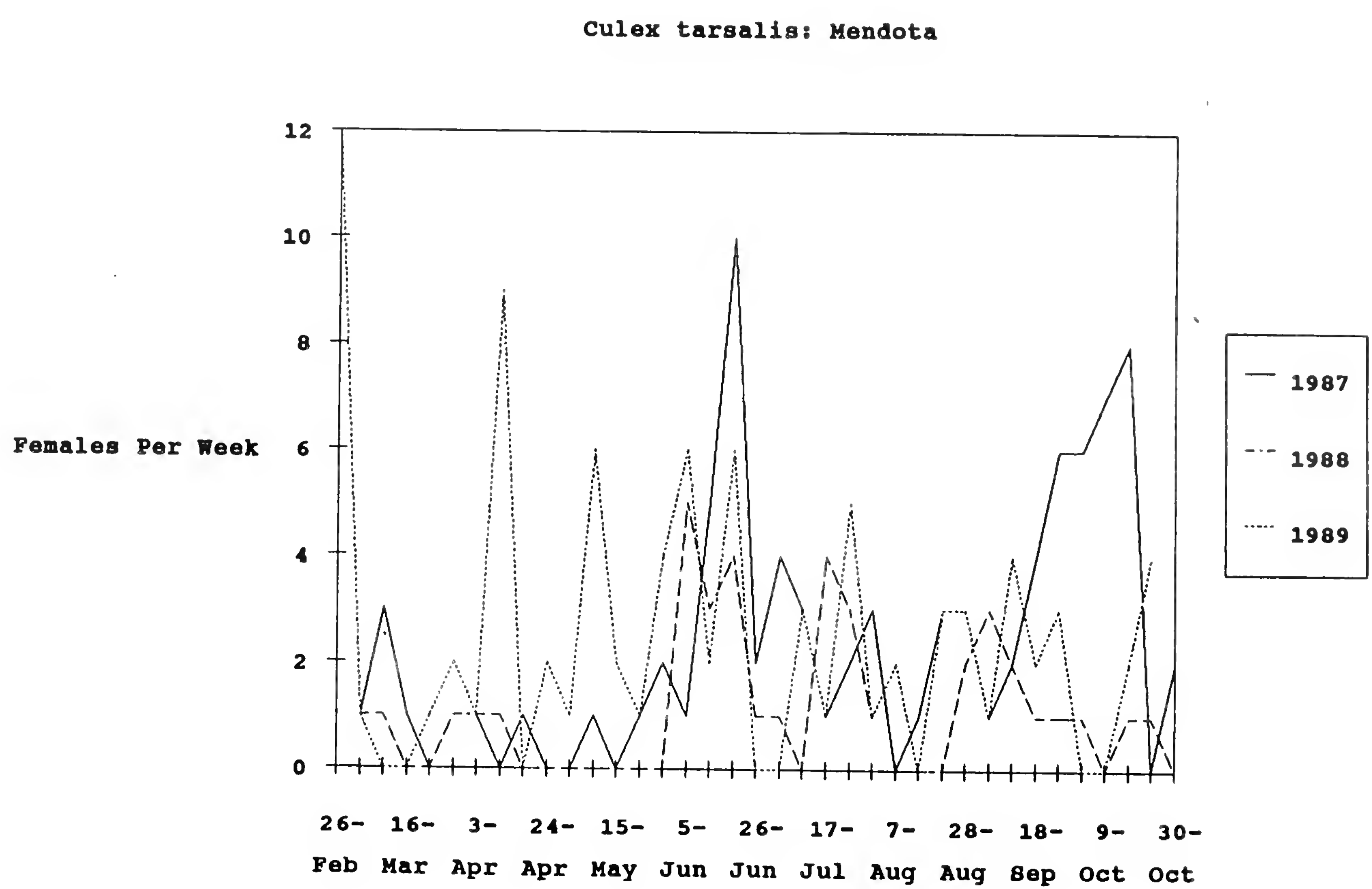
Culex tarsalis: Firebaugh



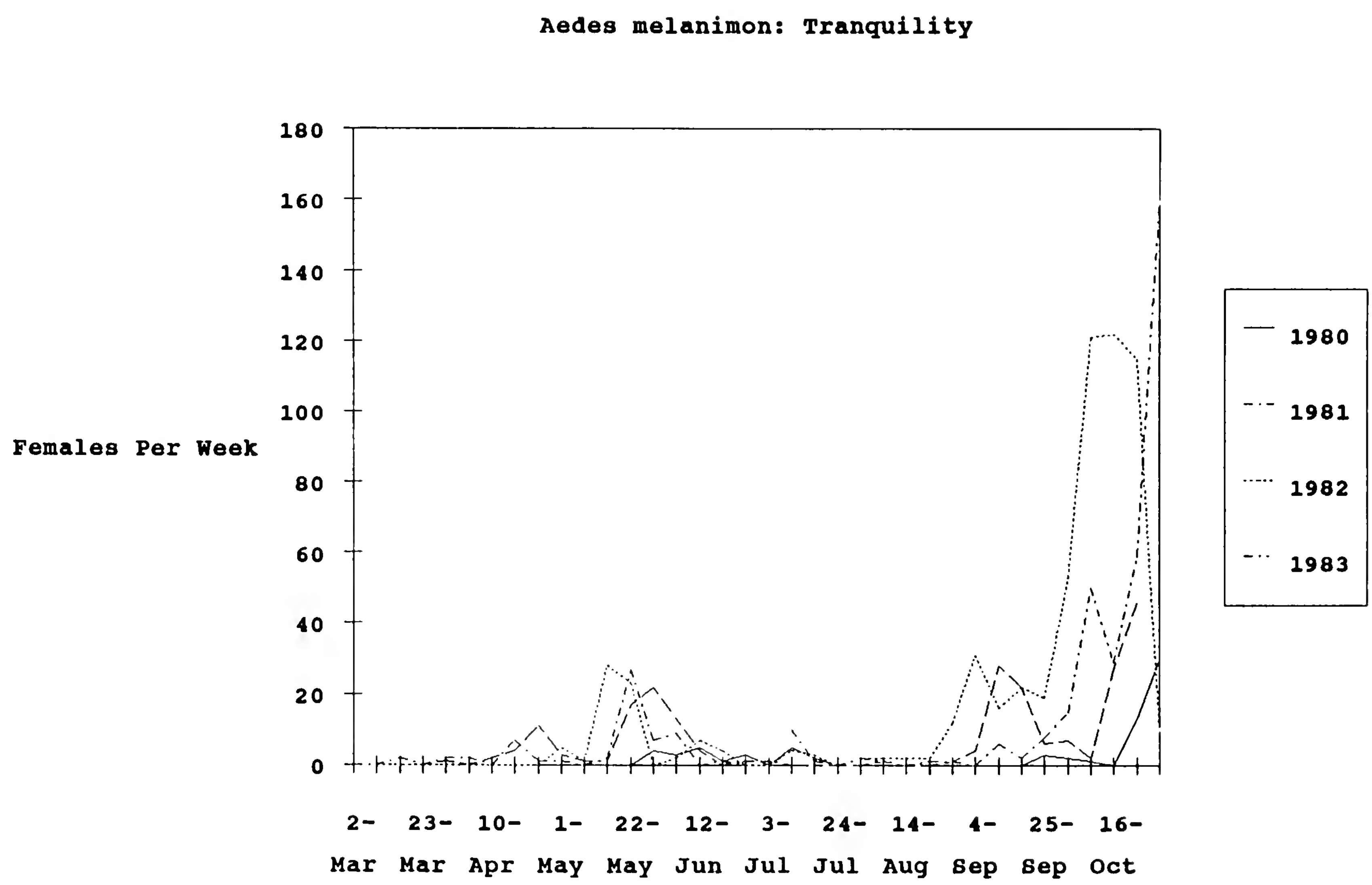
Culex tarsalis: Mendota

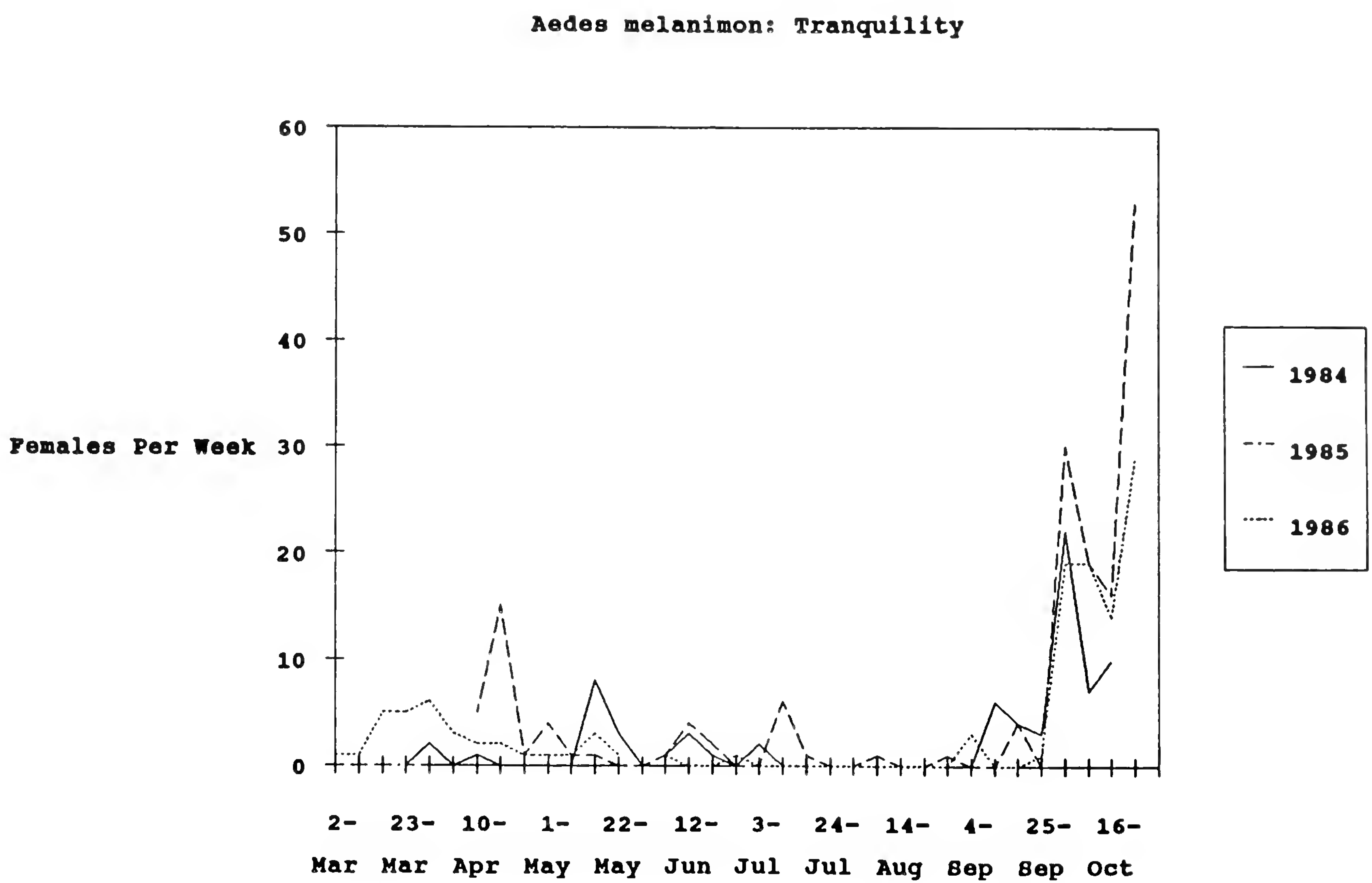



Culex tarsalis: Mendota
Females Per Week
35
30
25
20
15
10
5
0
26- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

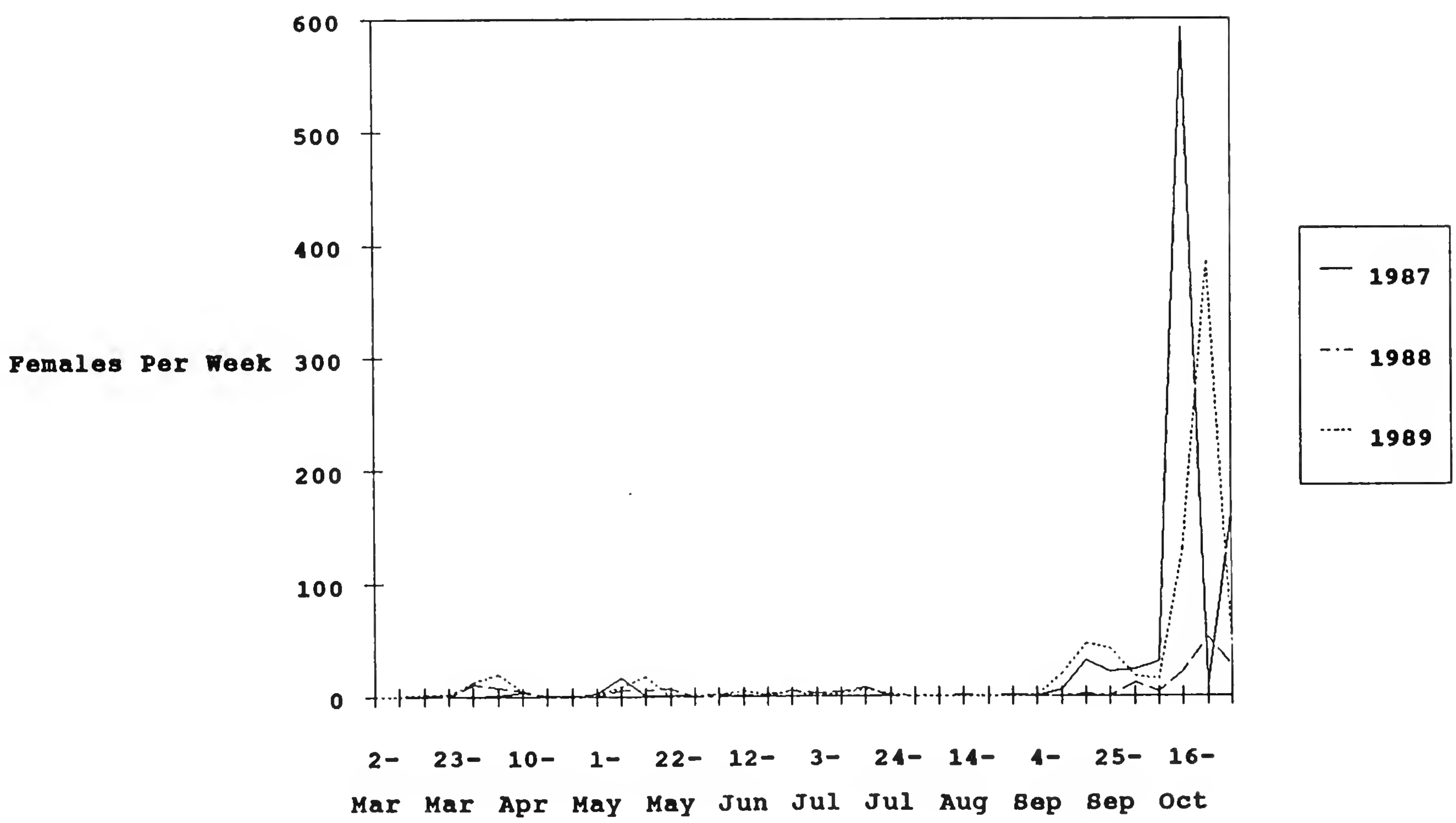


Culex tarsalis: Mendota
Females Per Week
12
10
8
6
4
2
0
26- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1987
1988
1989

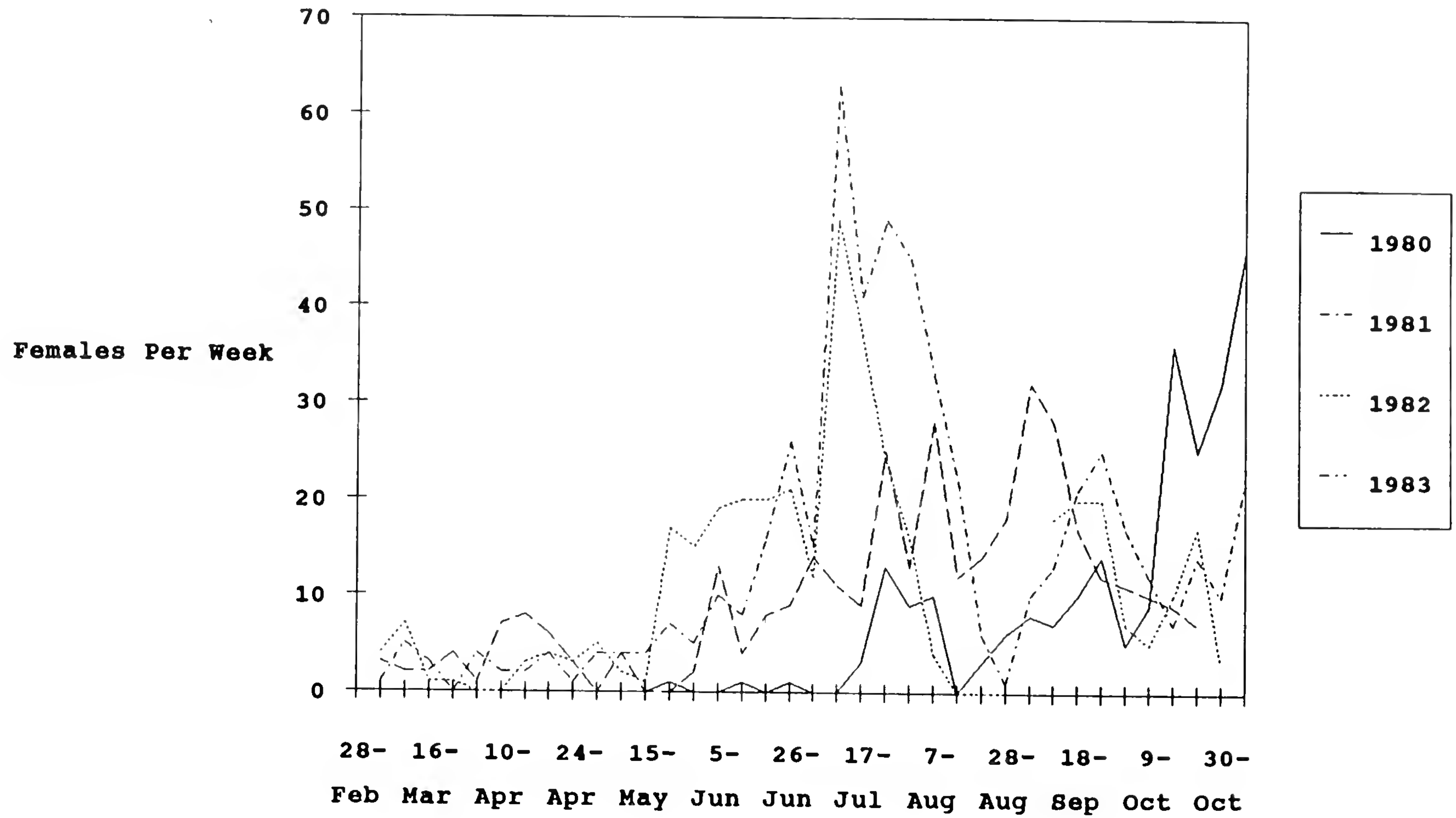

Aedes melanimon: Tranquility
Females Per Week
180
160
140
120
100
80
60
40
20
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1980
1981
1982
1983


Aedes melanimon: Tranquility
Females Per Week
60
50
40
30
20
10
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1984
1985
1986

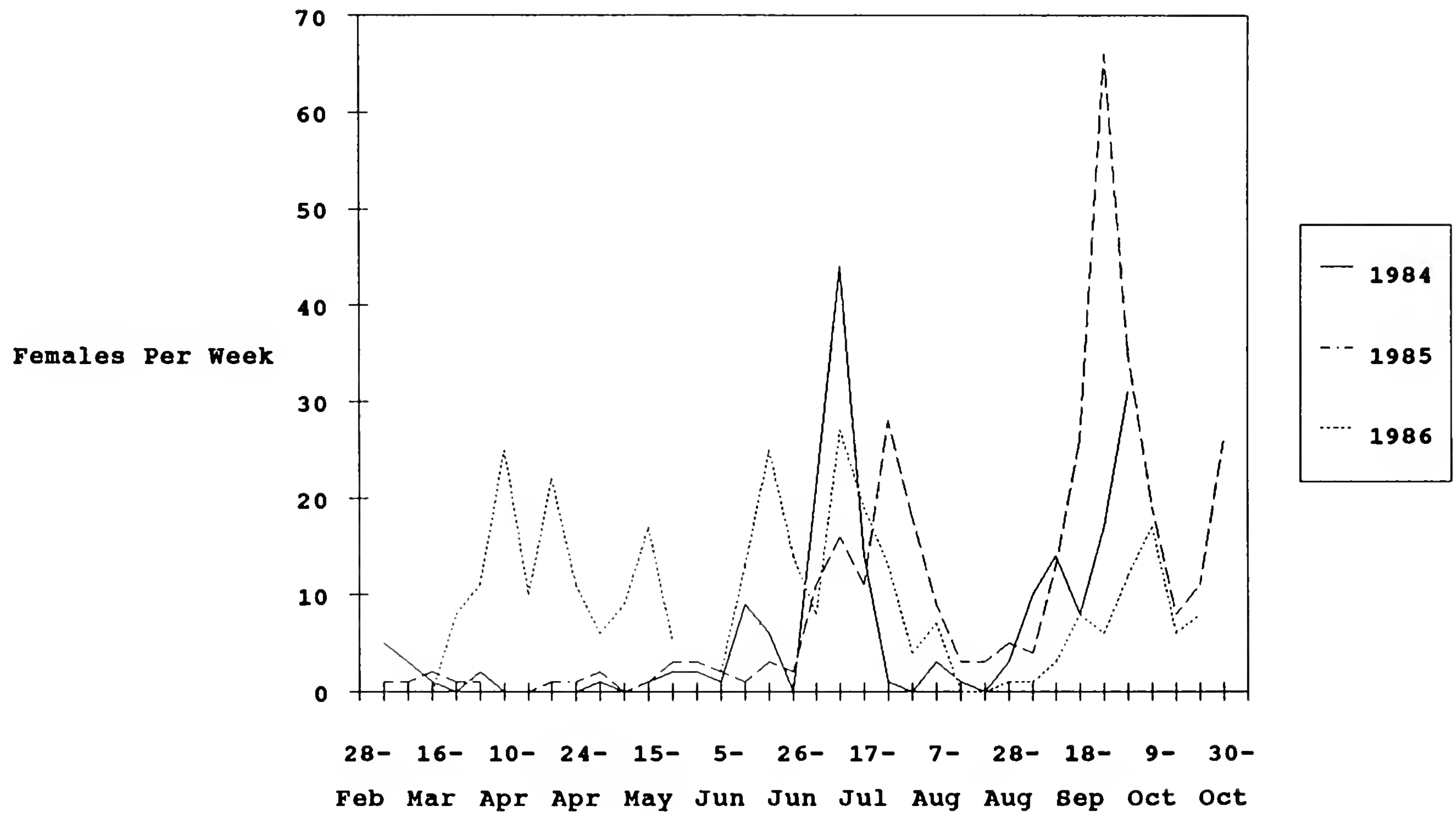
Aedes melanimon: Tranquility



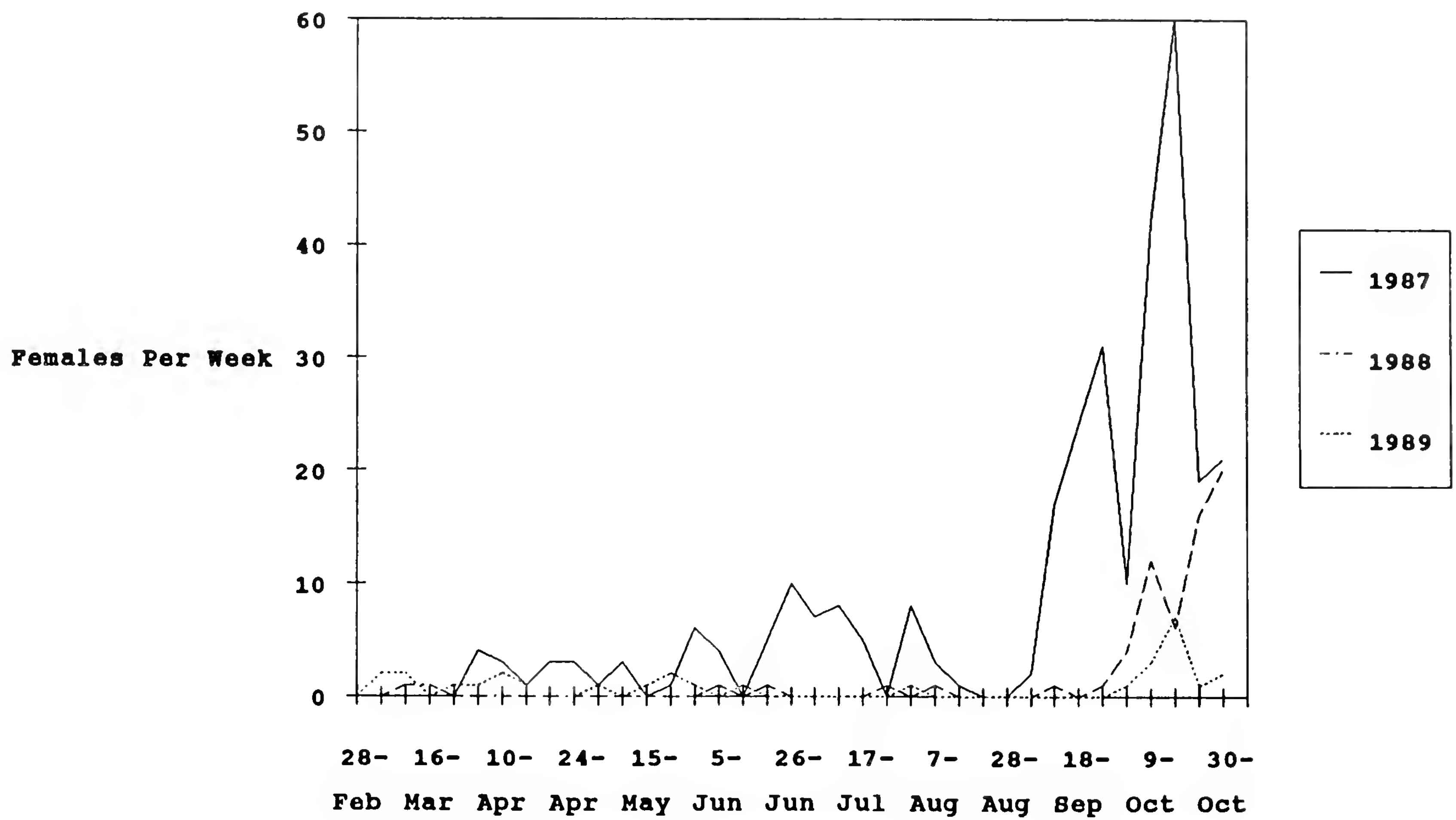
Culex tarsalis: Canuta



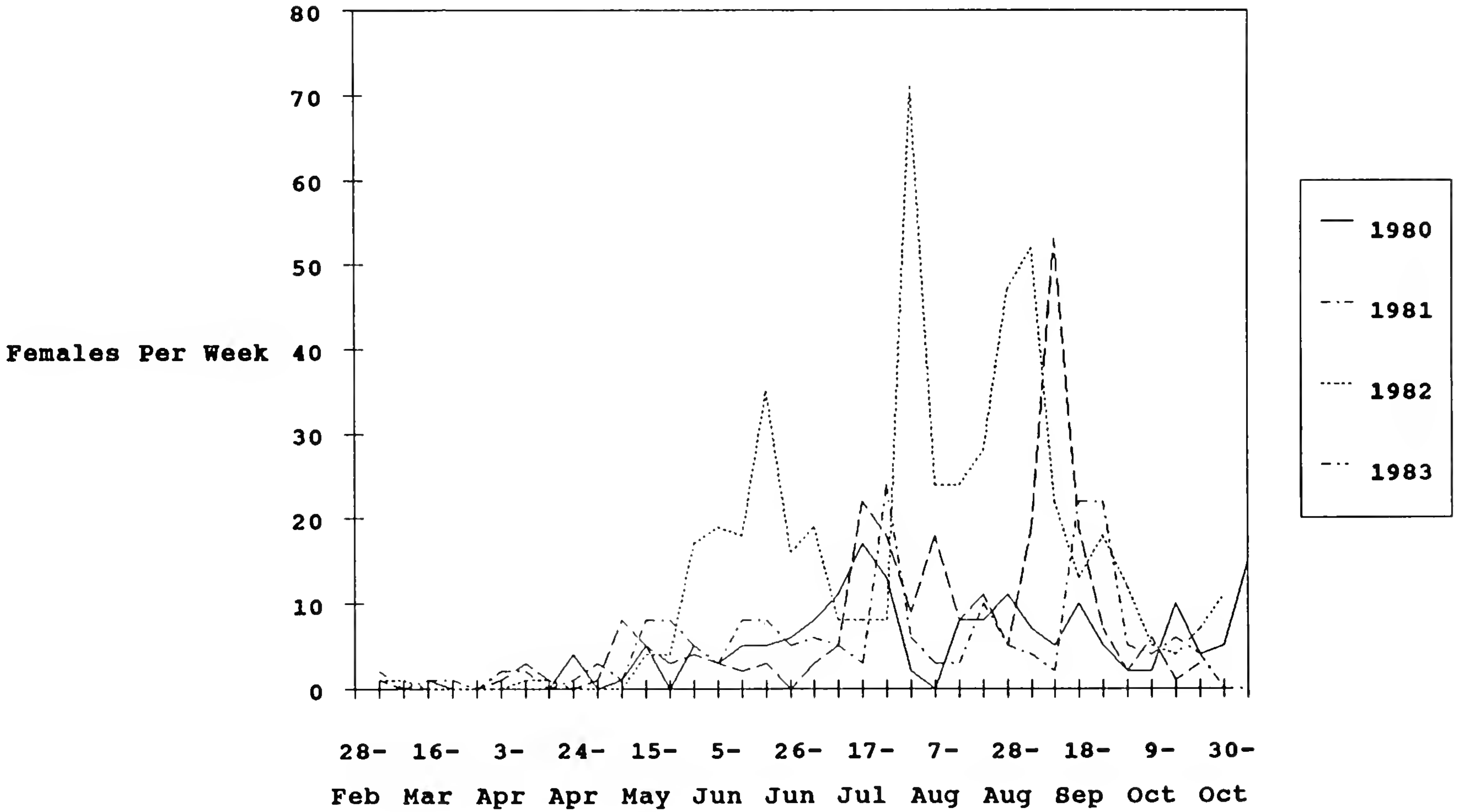
Culex tarsalis: Canuta

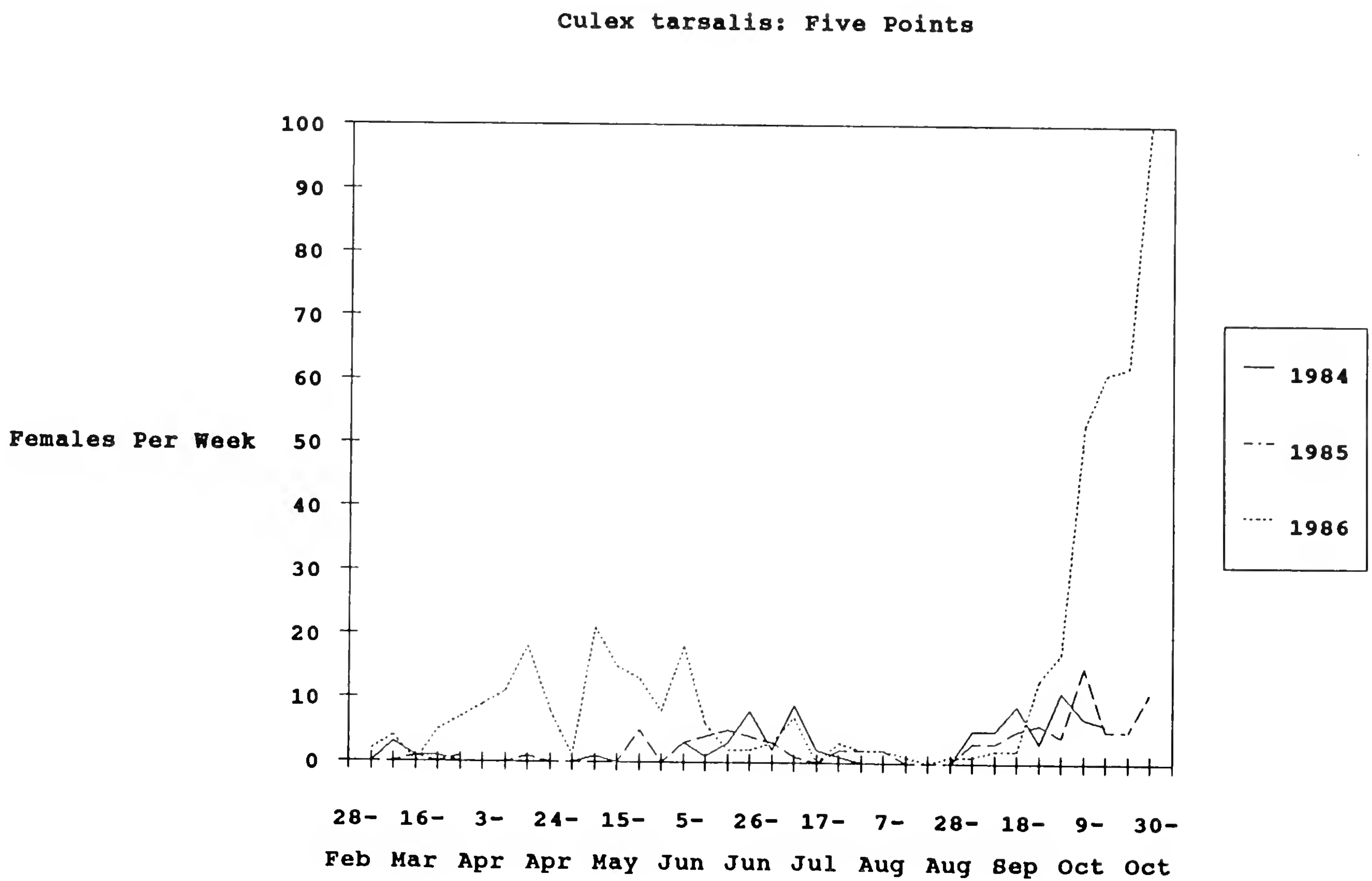


Culex tarsalis: Canuta



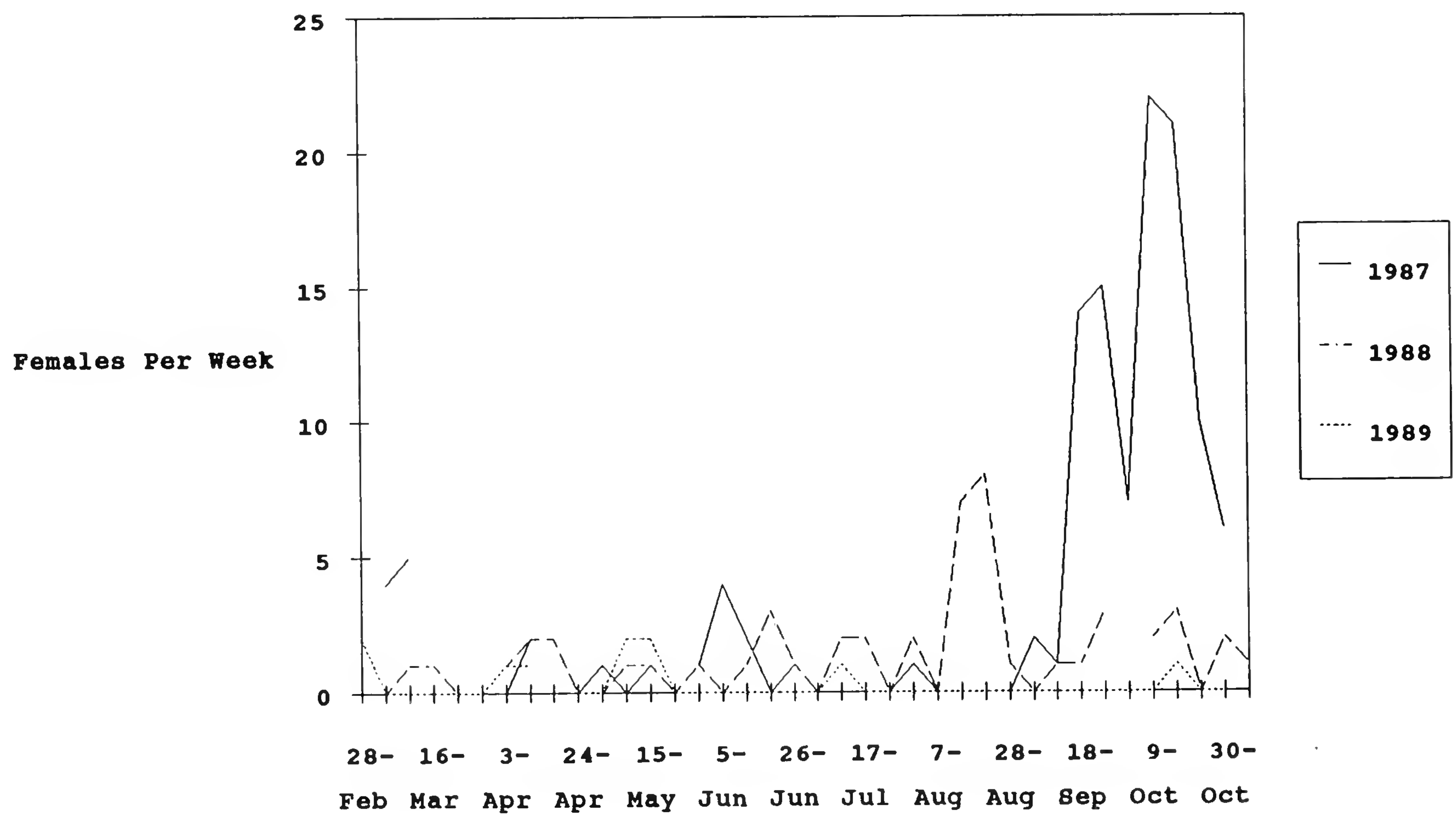
Culex tarsalis: Five Points



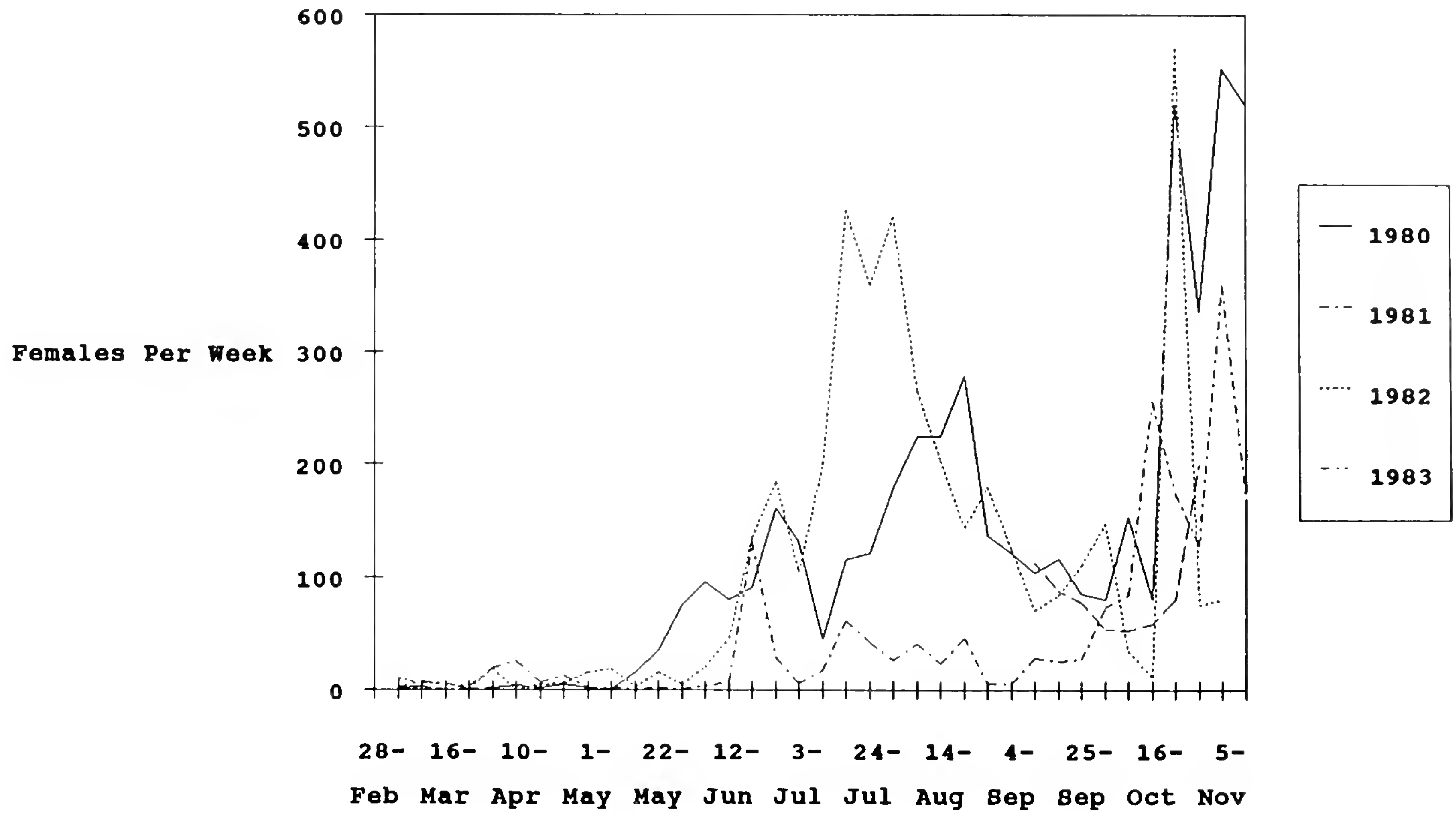


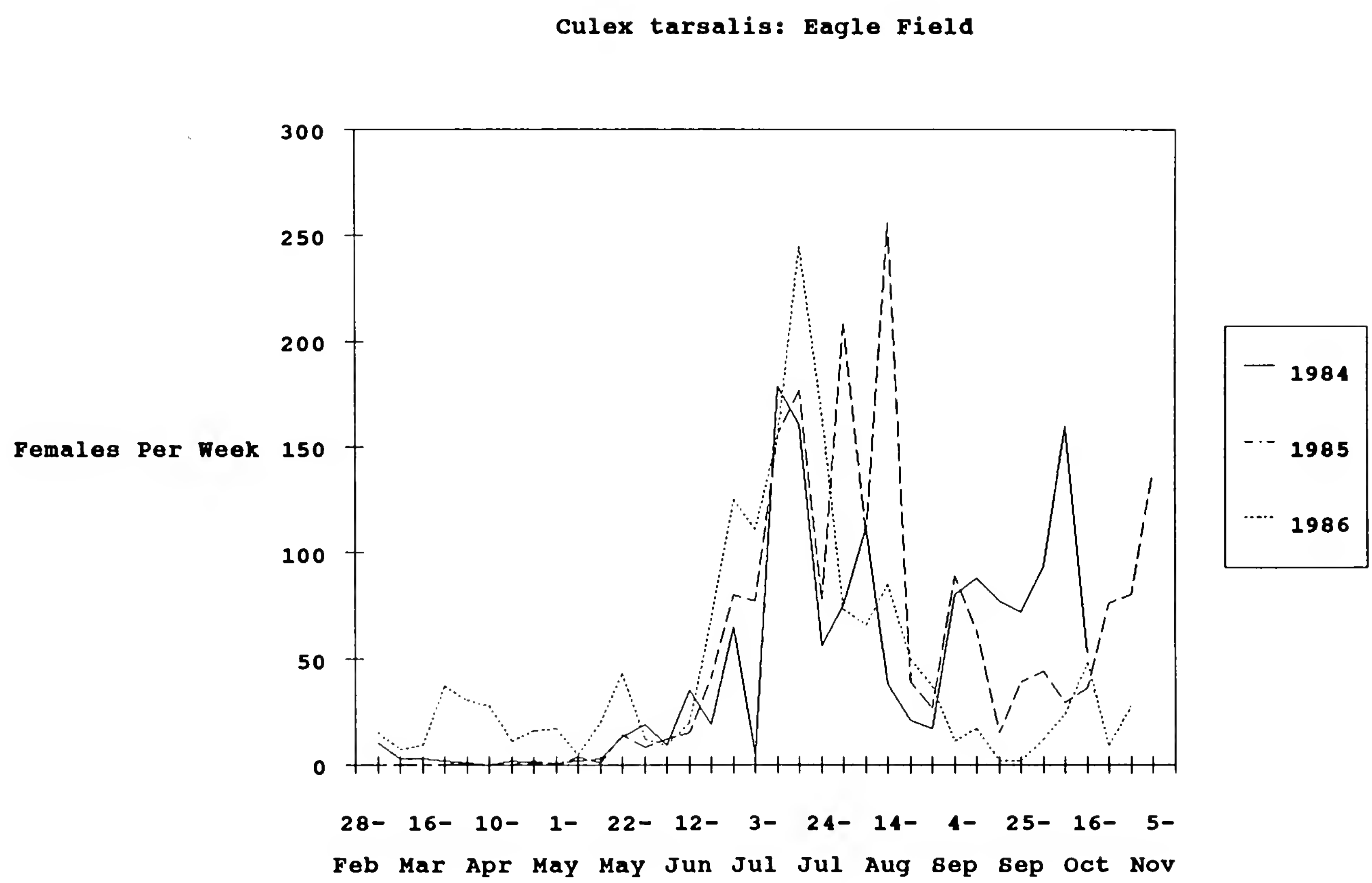
Culex tarsalis: Five Points
Females Per Week
100
90
80
70
60
50
40
30
20
10
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

Culex tarsalis: Five Points

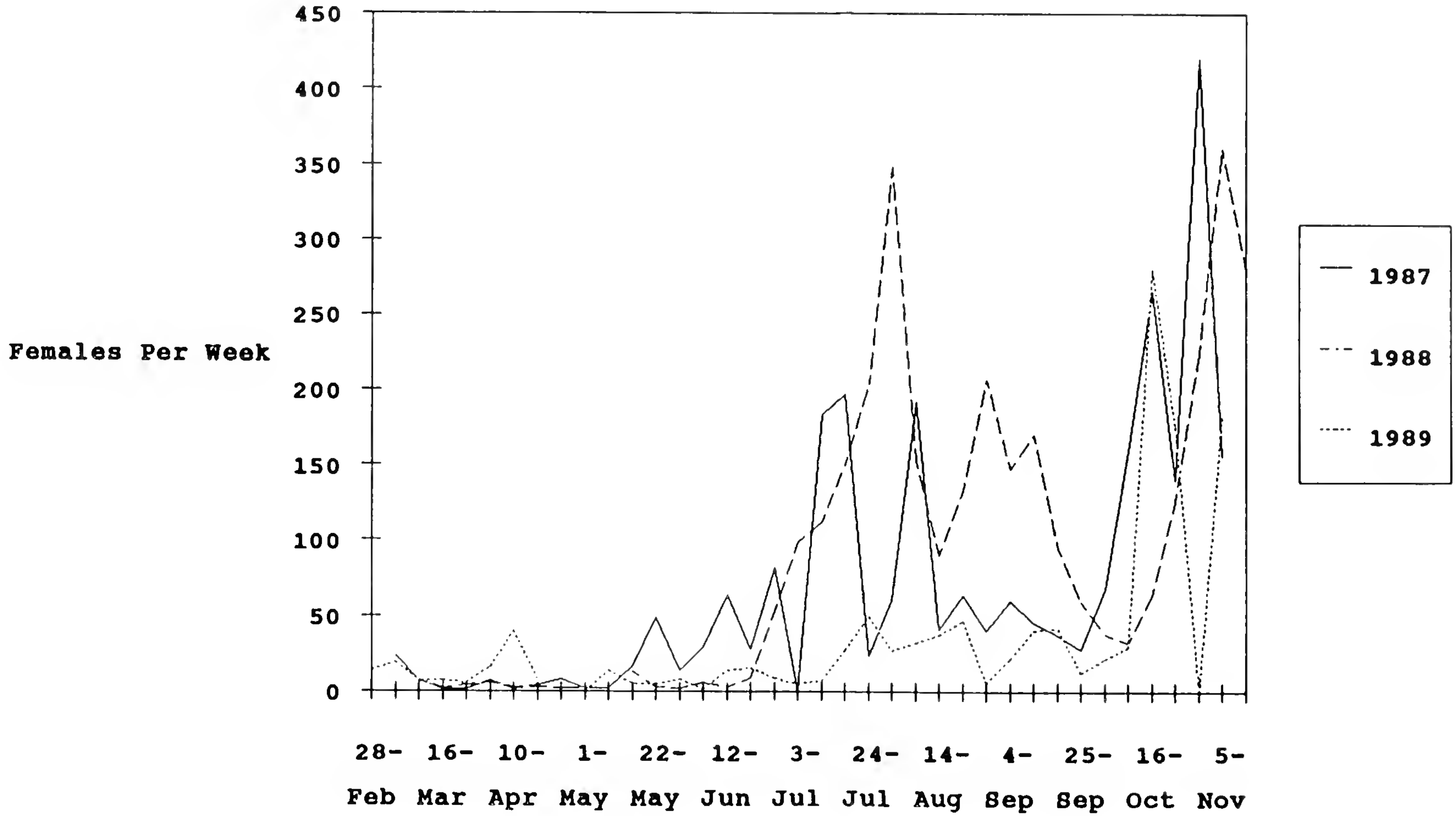


Culex tarsalis: Eagle Field

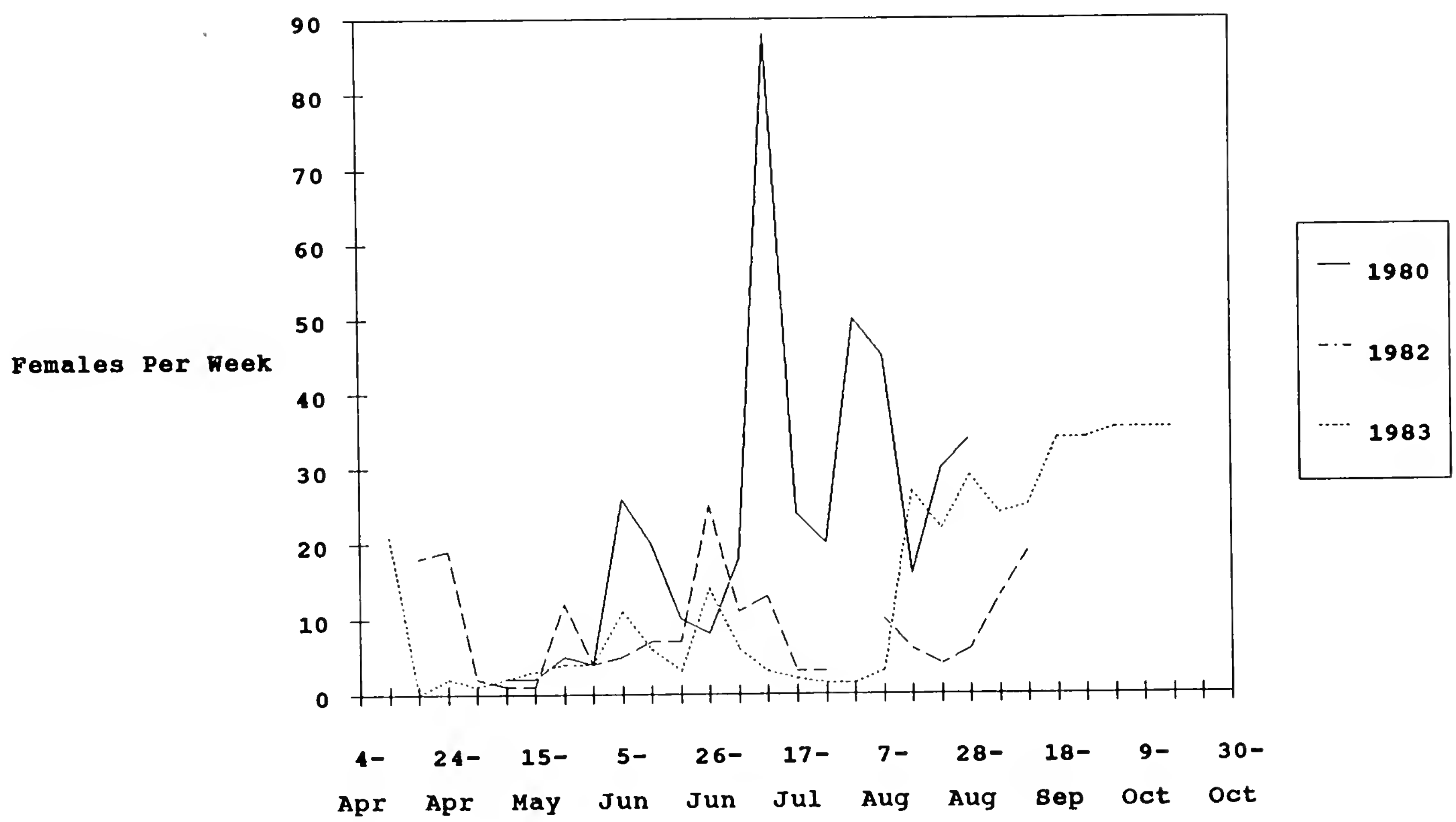


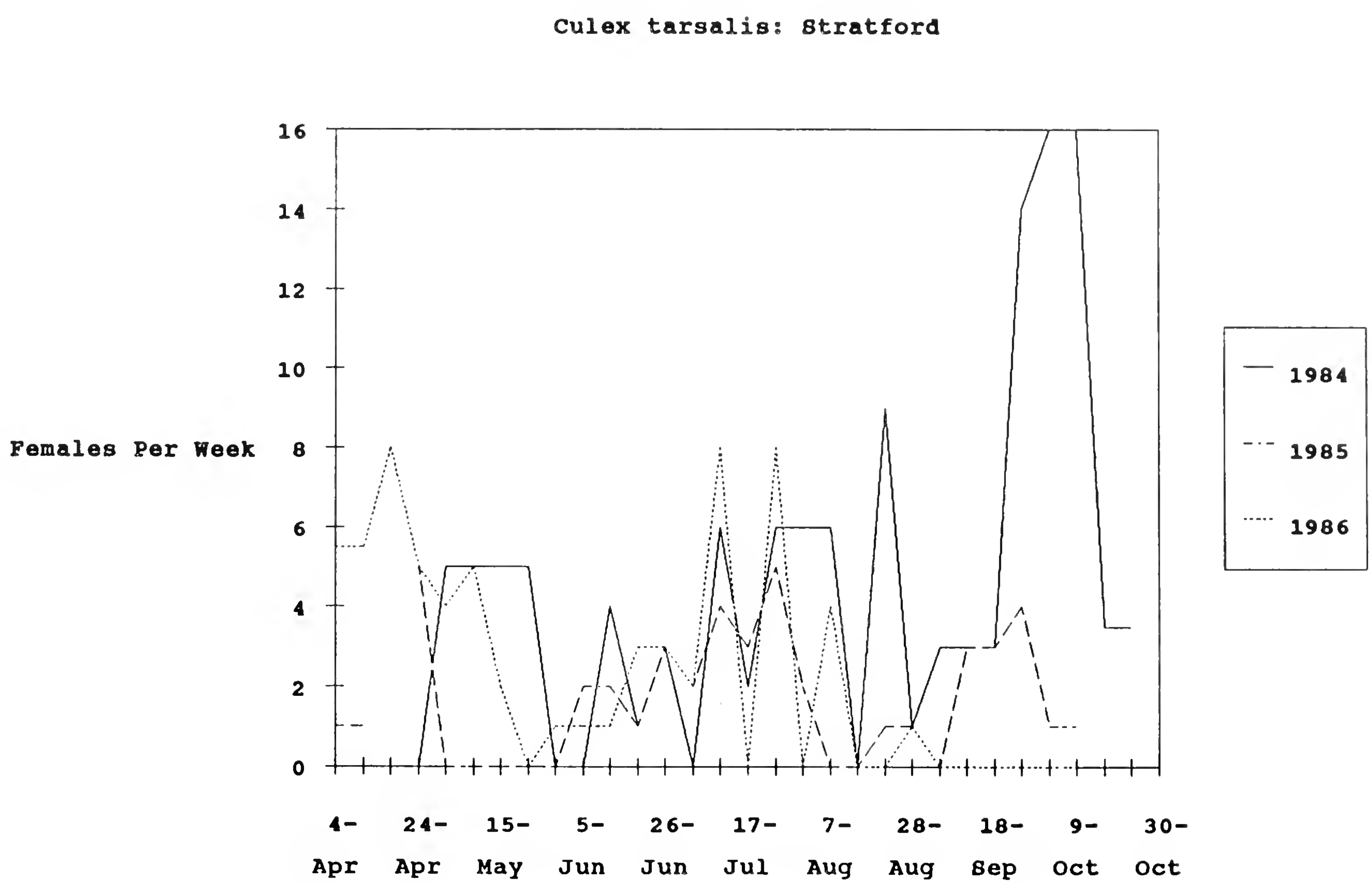

Culex tarsalis: Eagle Field
Females Per Week
300
250
200
150
100
50
0
28- Feb
16- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
5- Nov
1984
1985
1986

Culex tarsalis: Eagle Field

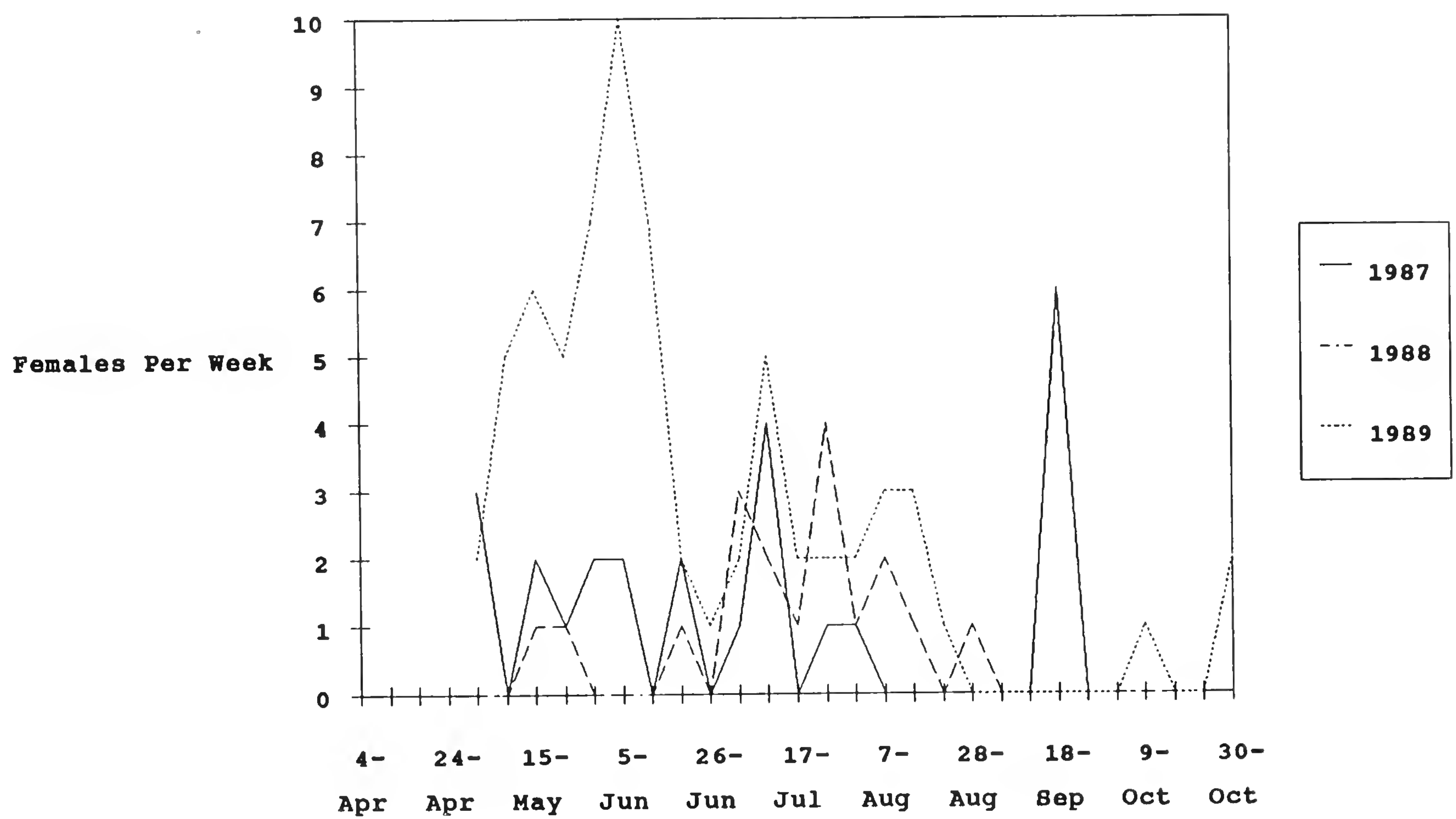


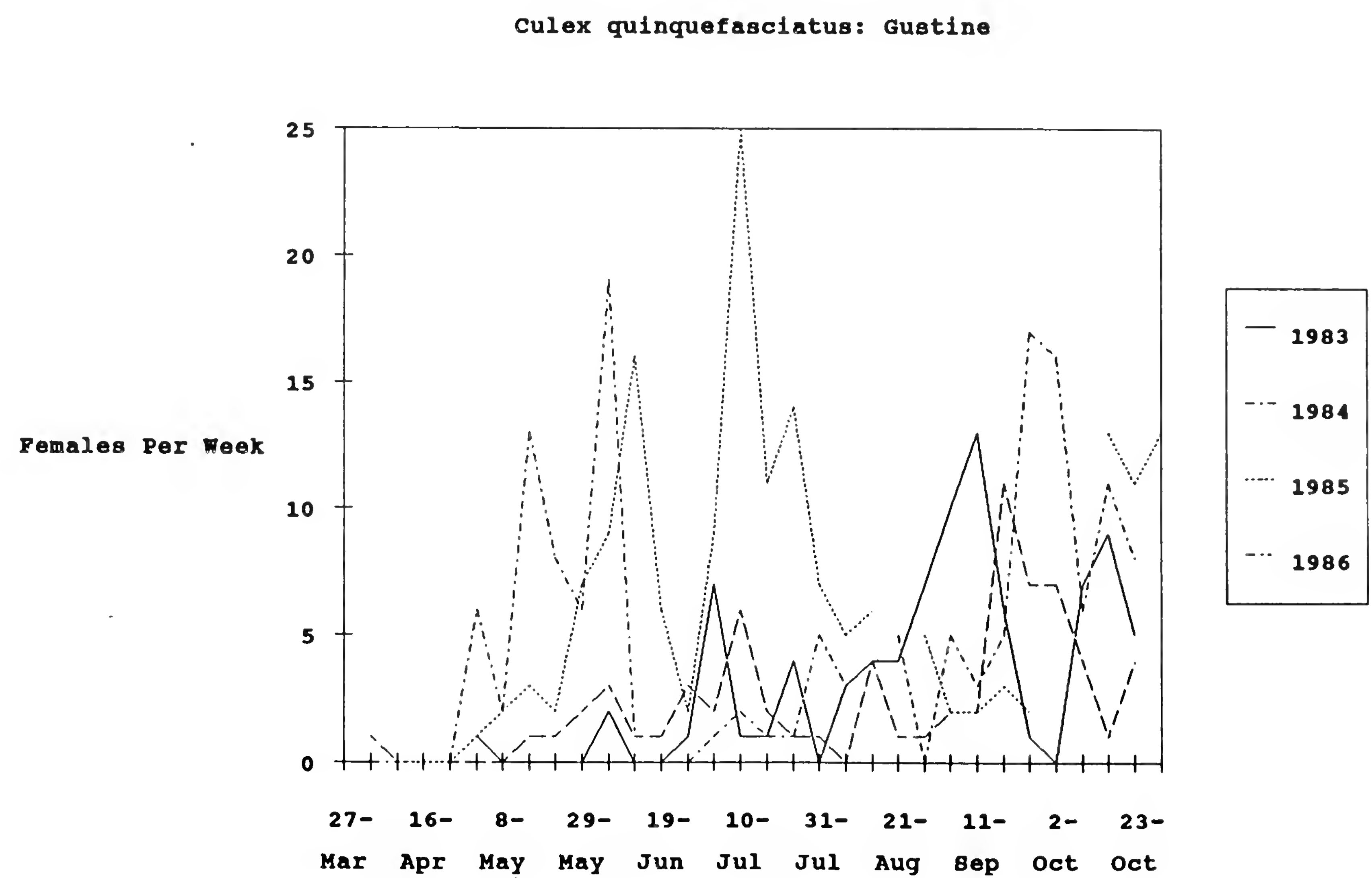
Culex tarsalis: Stratford

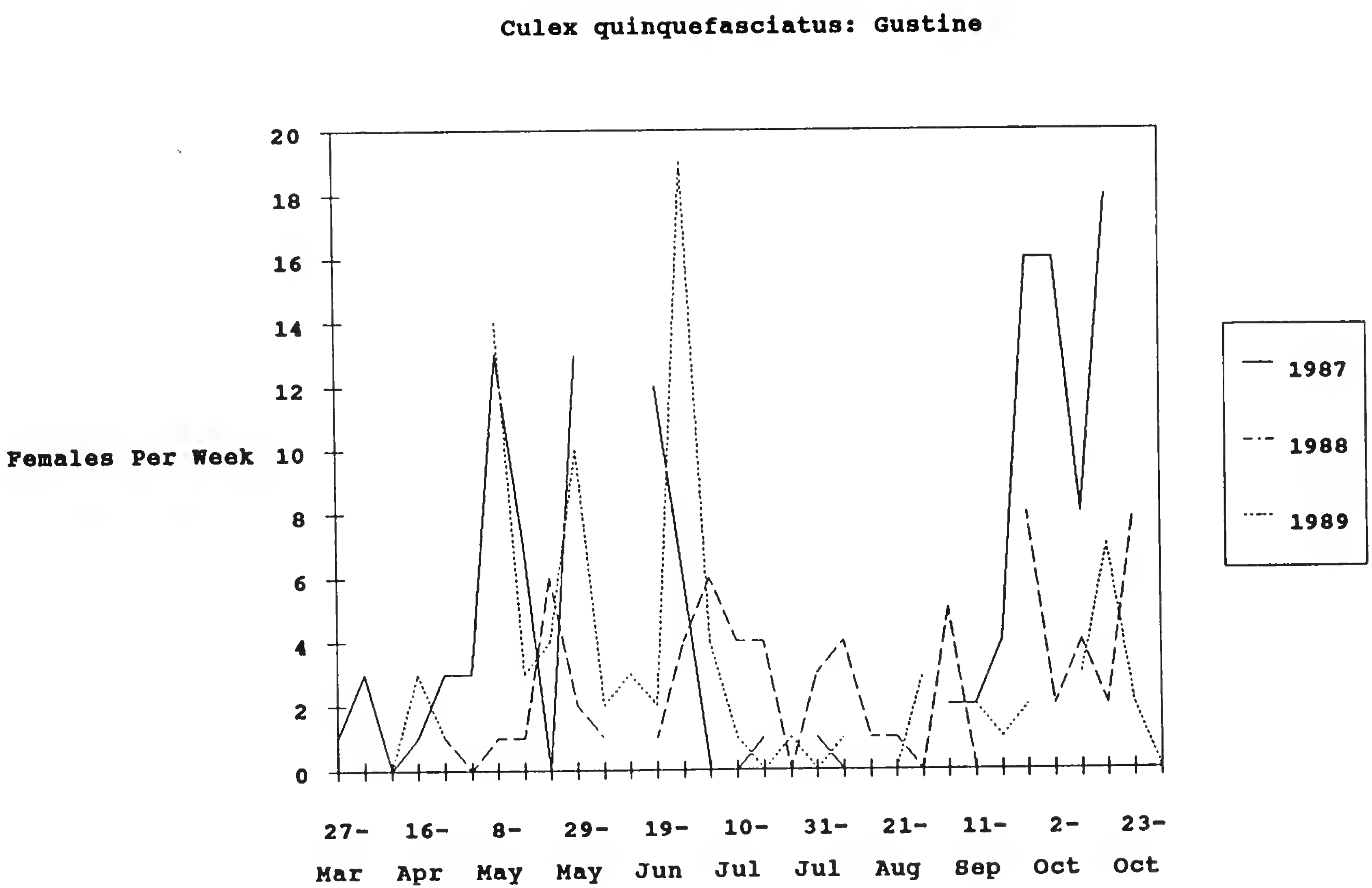



Culex tarsalis: Stratford
Females Per Week
16
14
12
10
8
6
4
2
0
4- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

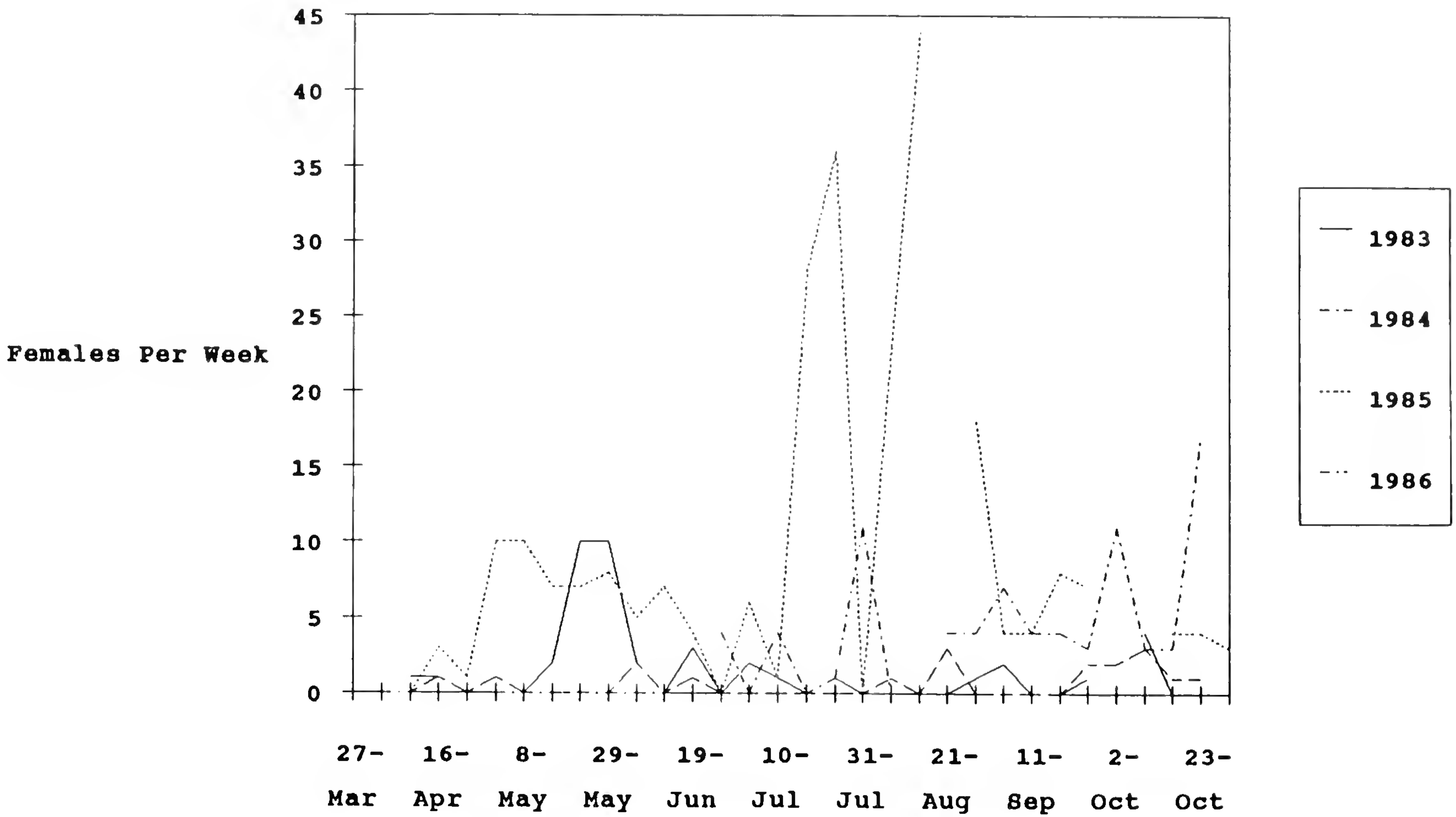
Culex tarsalis: Stratford



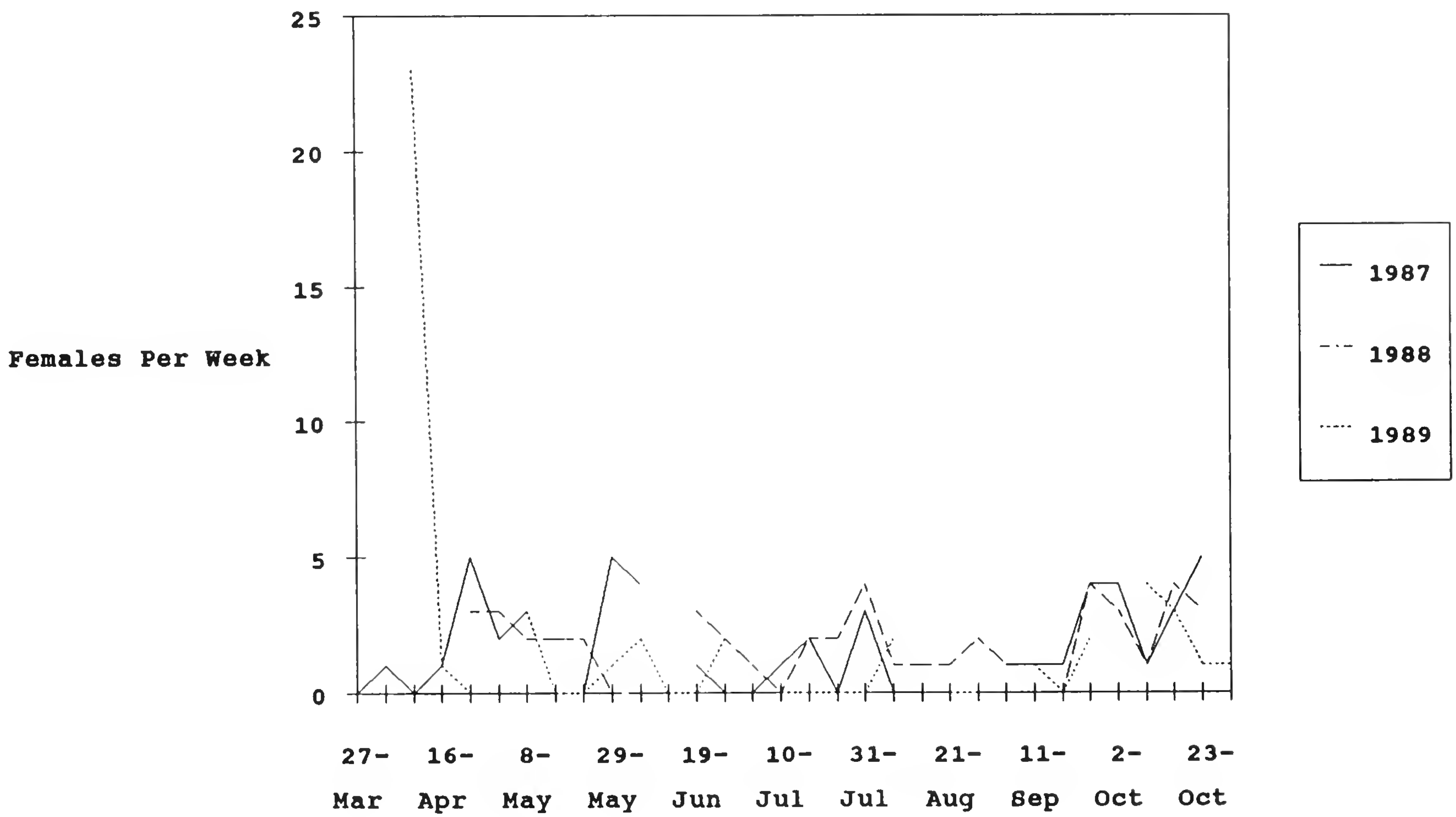

Culex quinquefasciatus: Gustine
Females Per Week
0
5
10
15
20
25
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1983
1984
1985
1986

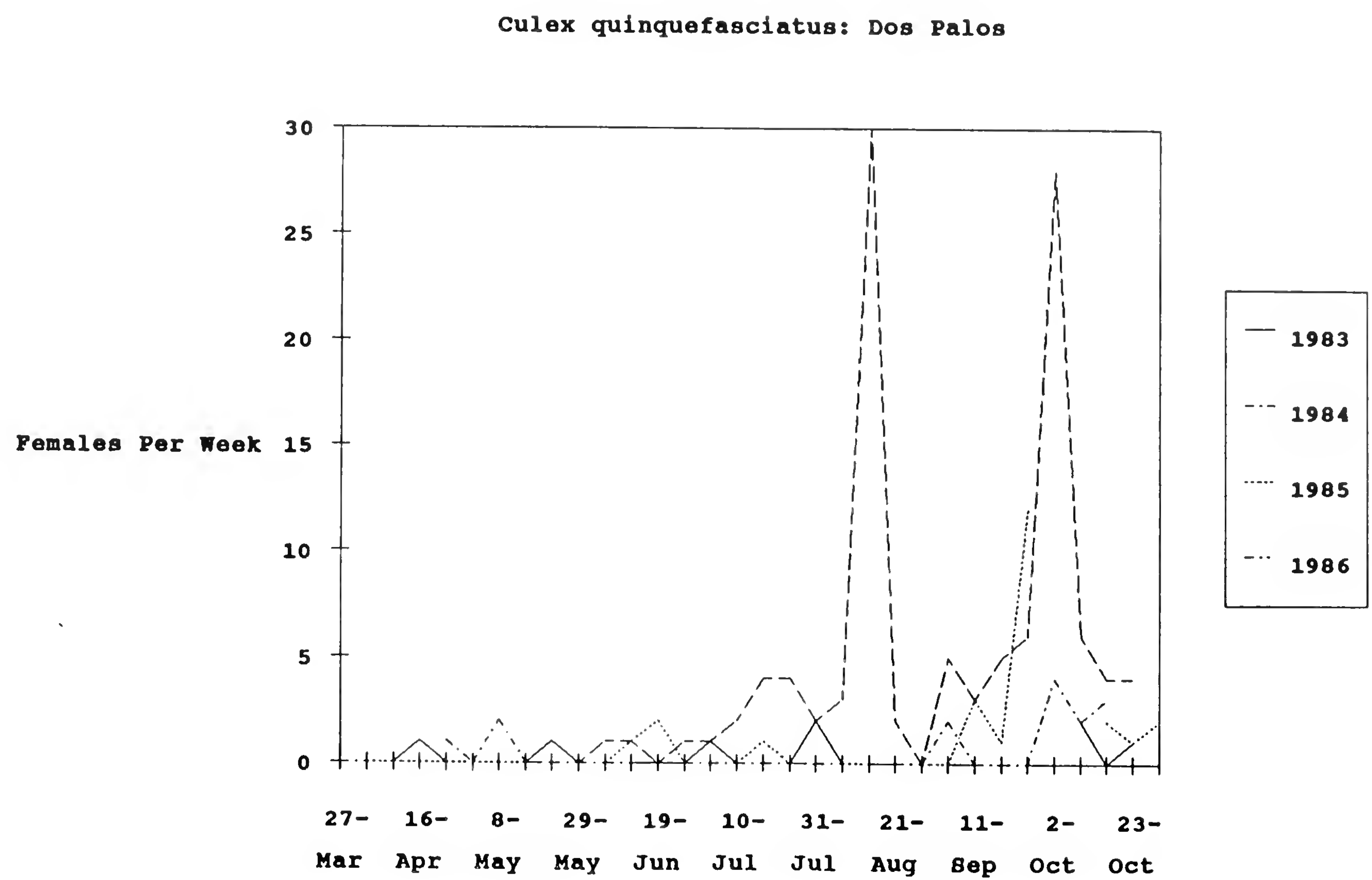

Culex quinquefasciatus: Gustine
Females Per Week
20
18
16
14
12
10
8
6
4
2
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

Culex quinquefasciatus: Los Banos

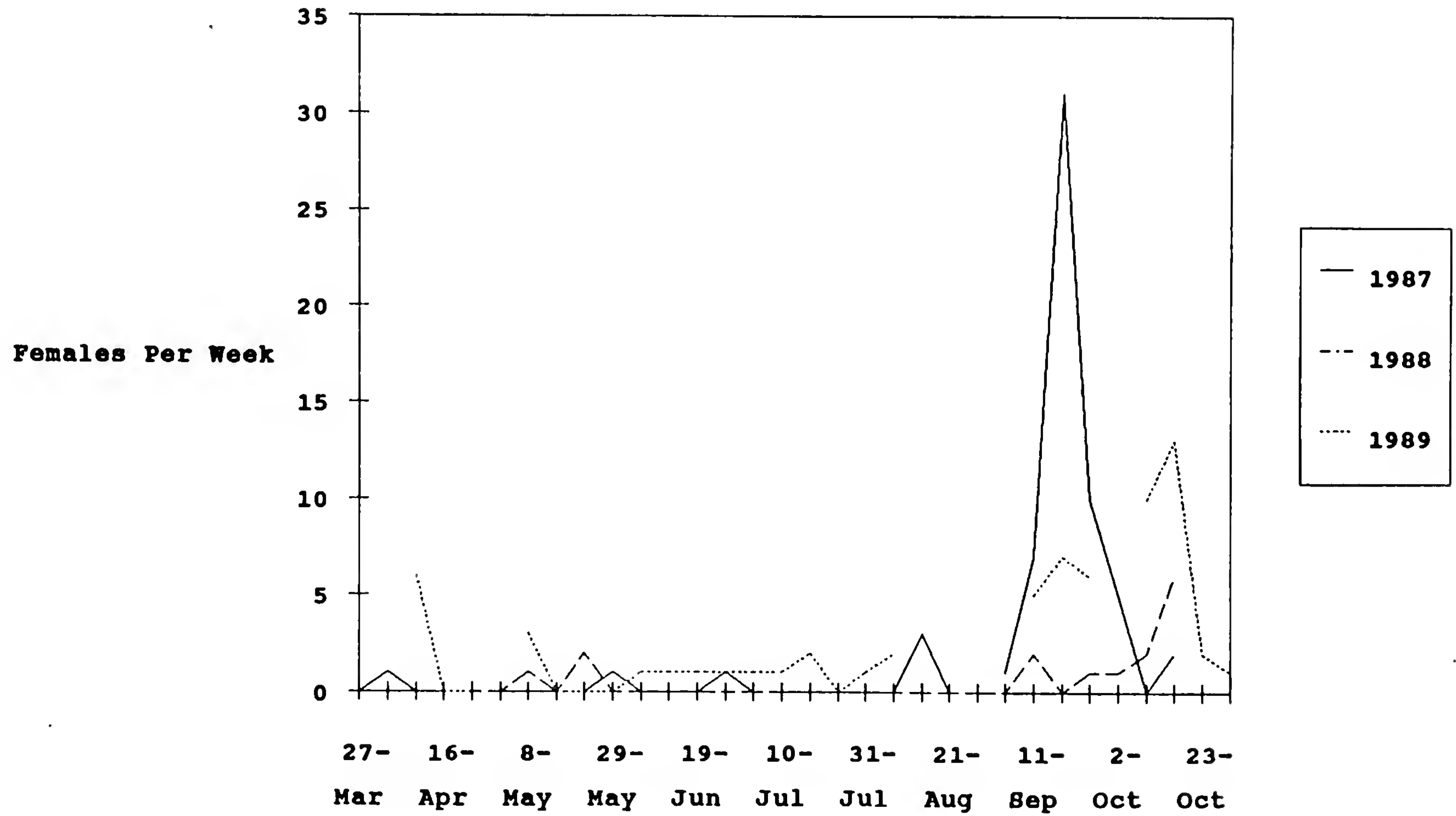


Culex quinquefasciatus: Los Banos

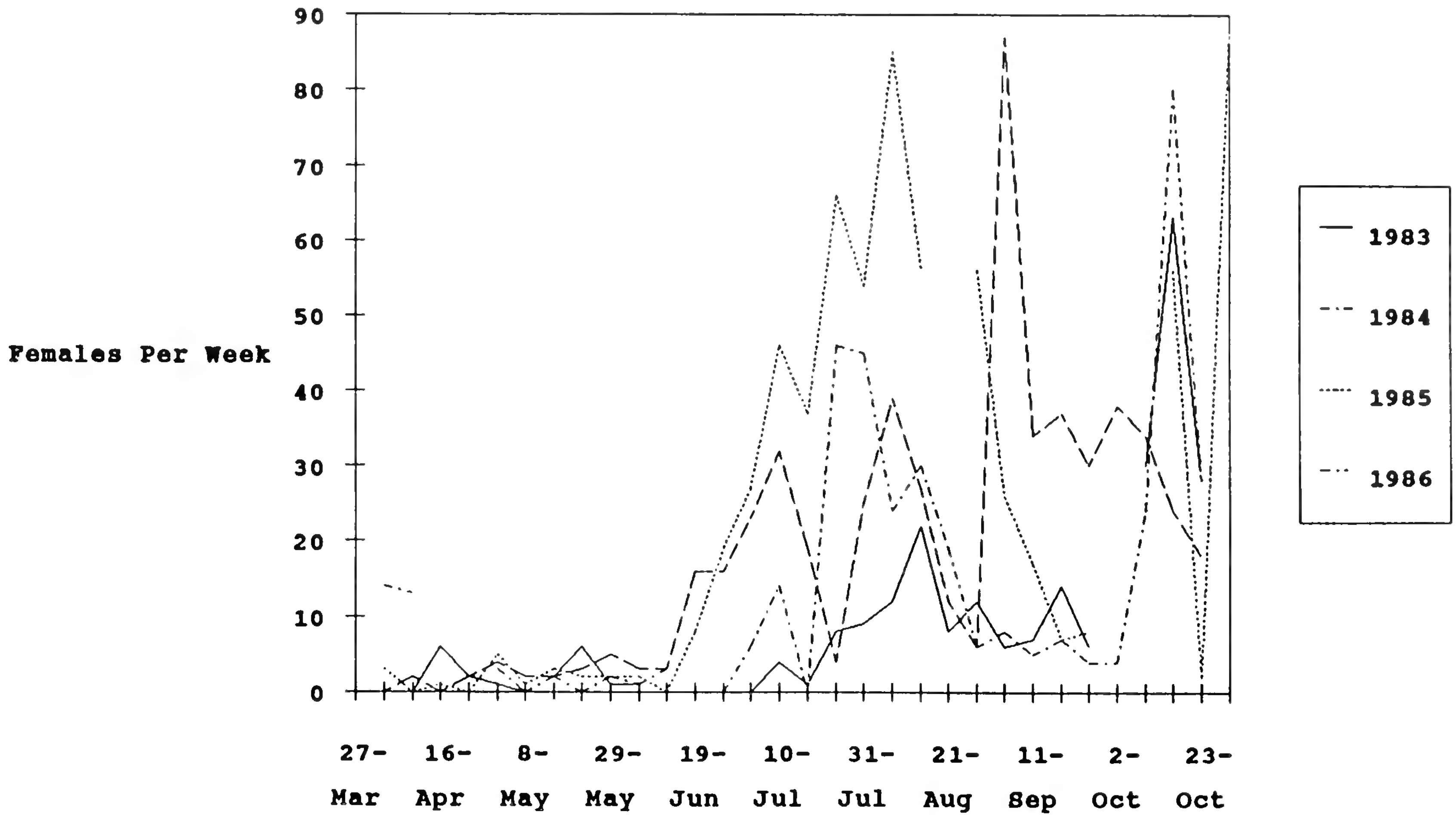



Culex quinquefasciatus: Dos Palos
Females Per Week
0
5
10
15
20
25
30
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1983
1984
1985
1986

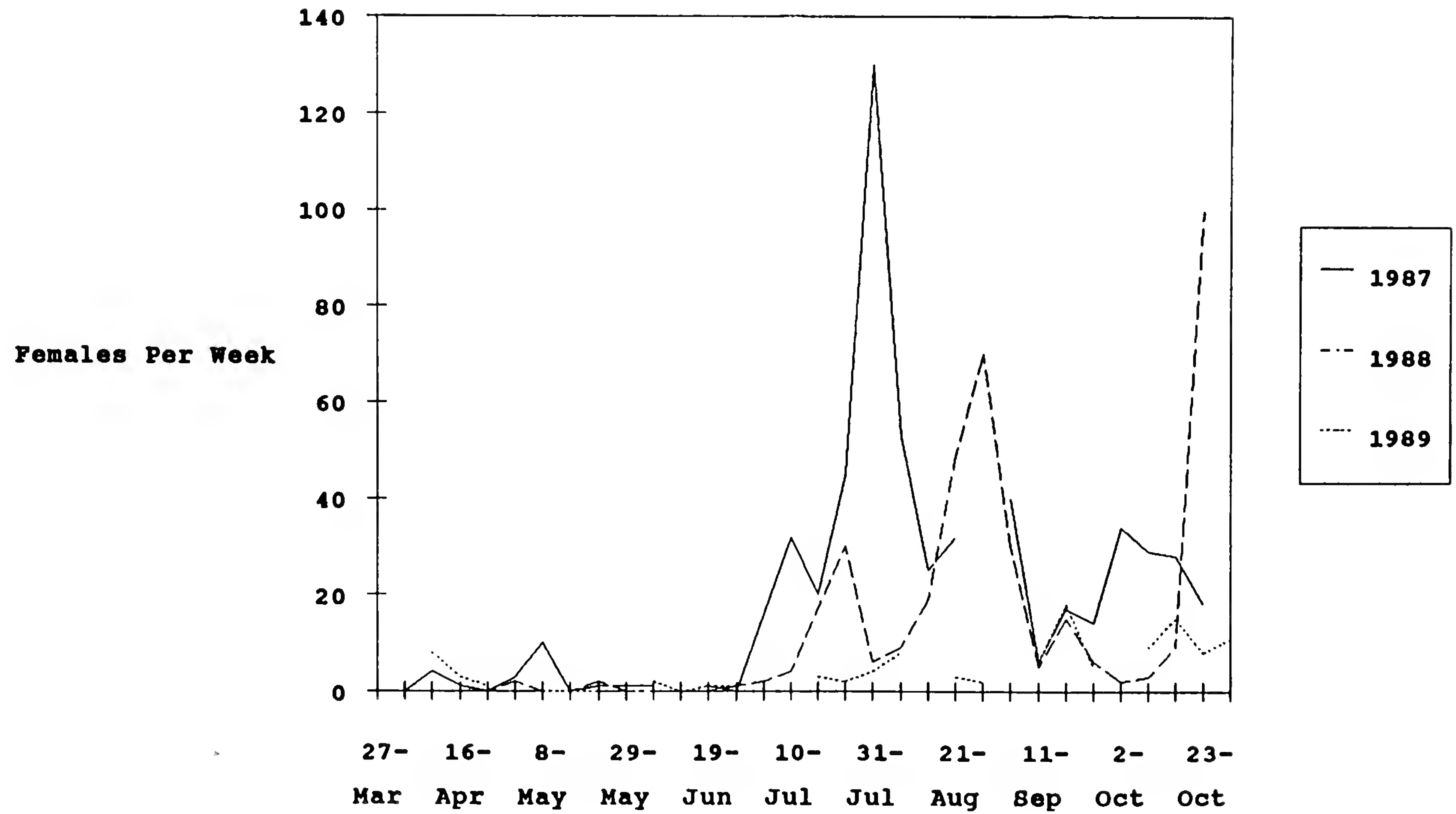
Culex quinquefasciatus: Dos Palos



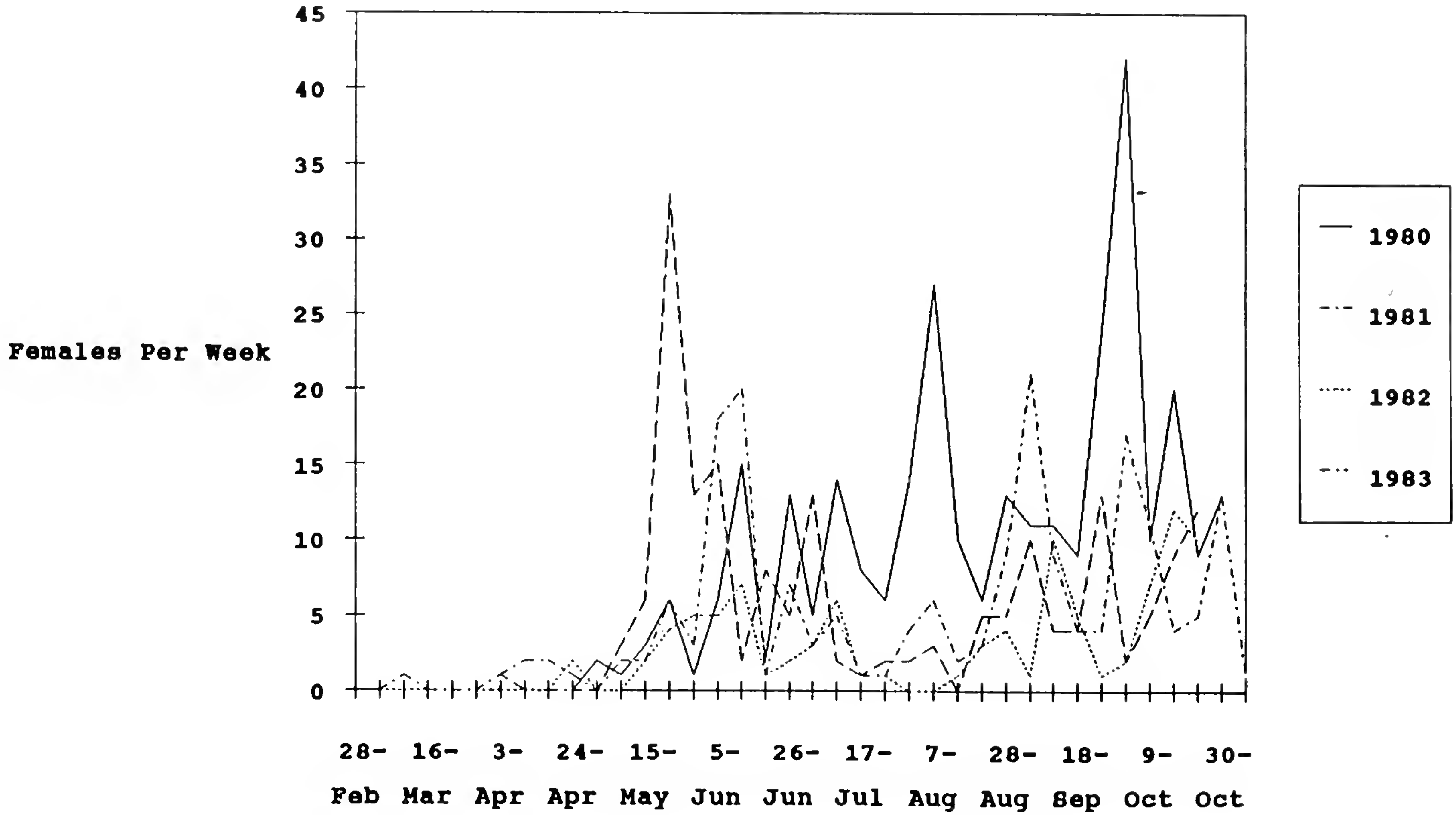
Culex tarsalis: South Dos Palos



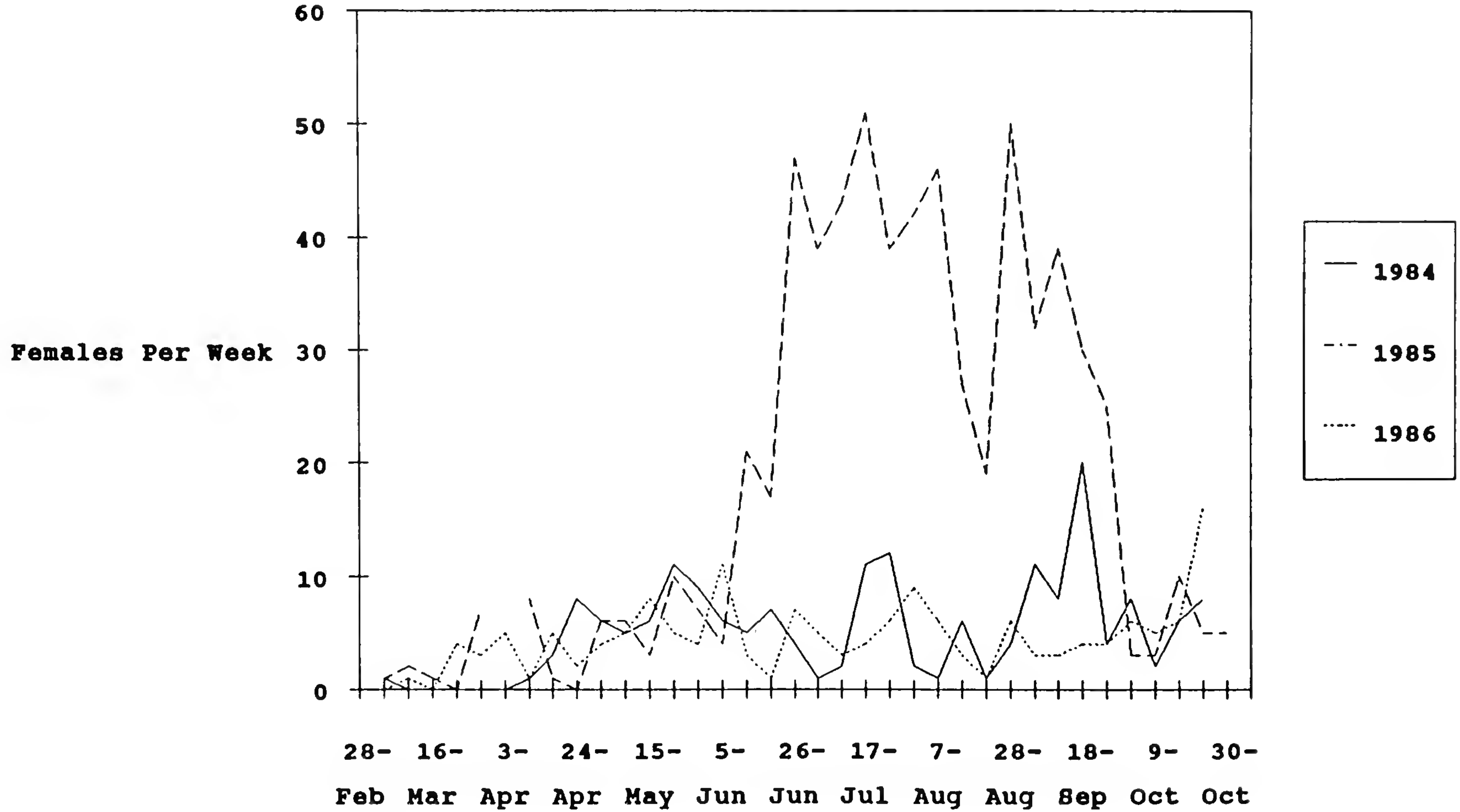
Culex tarsalis: South Dos Palos



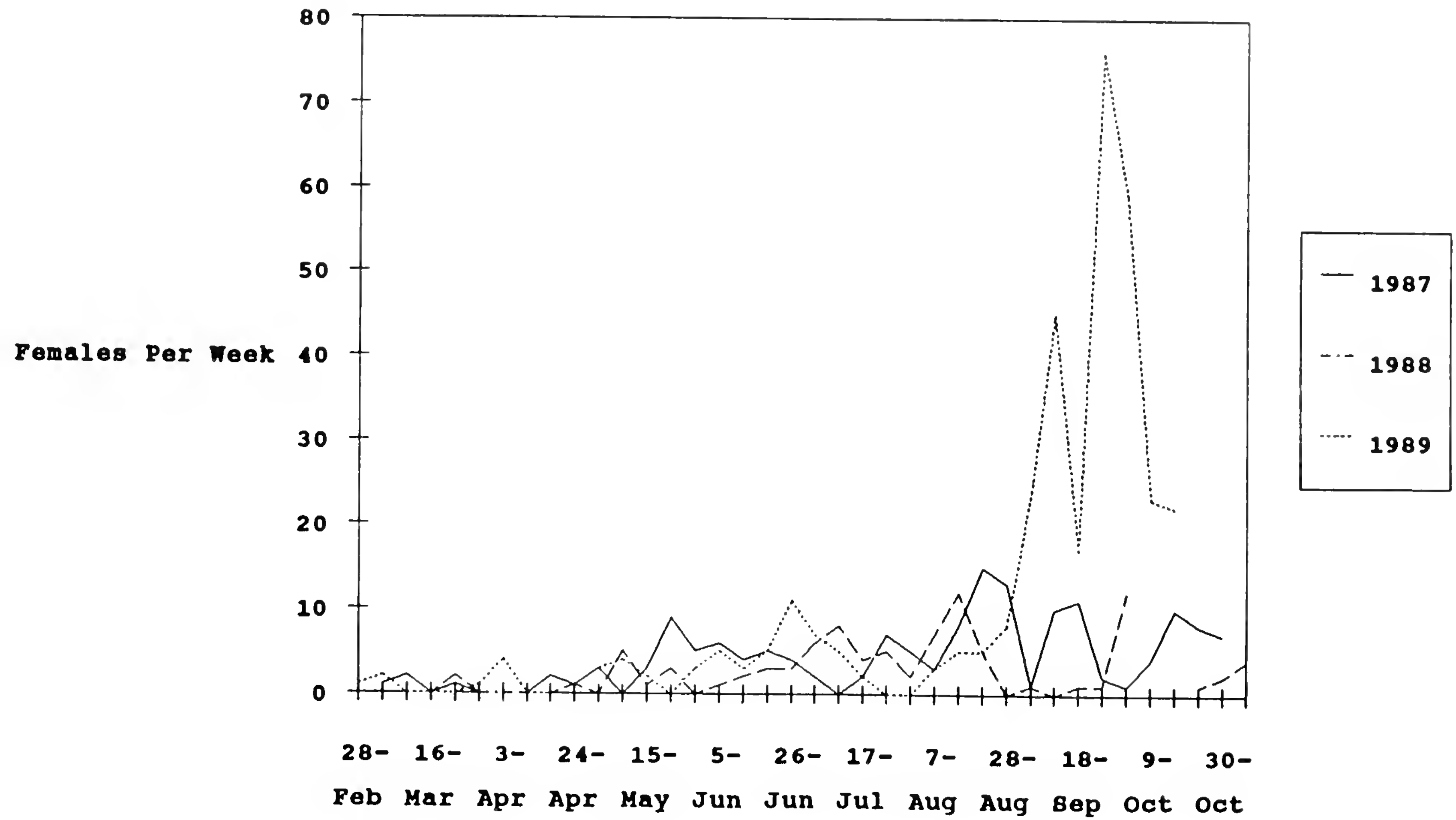
Culex quinquefasciatus: Firebaugh

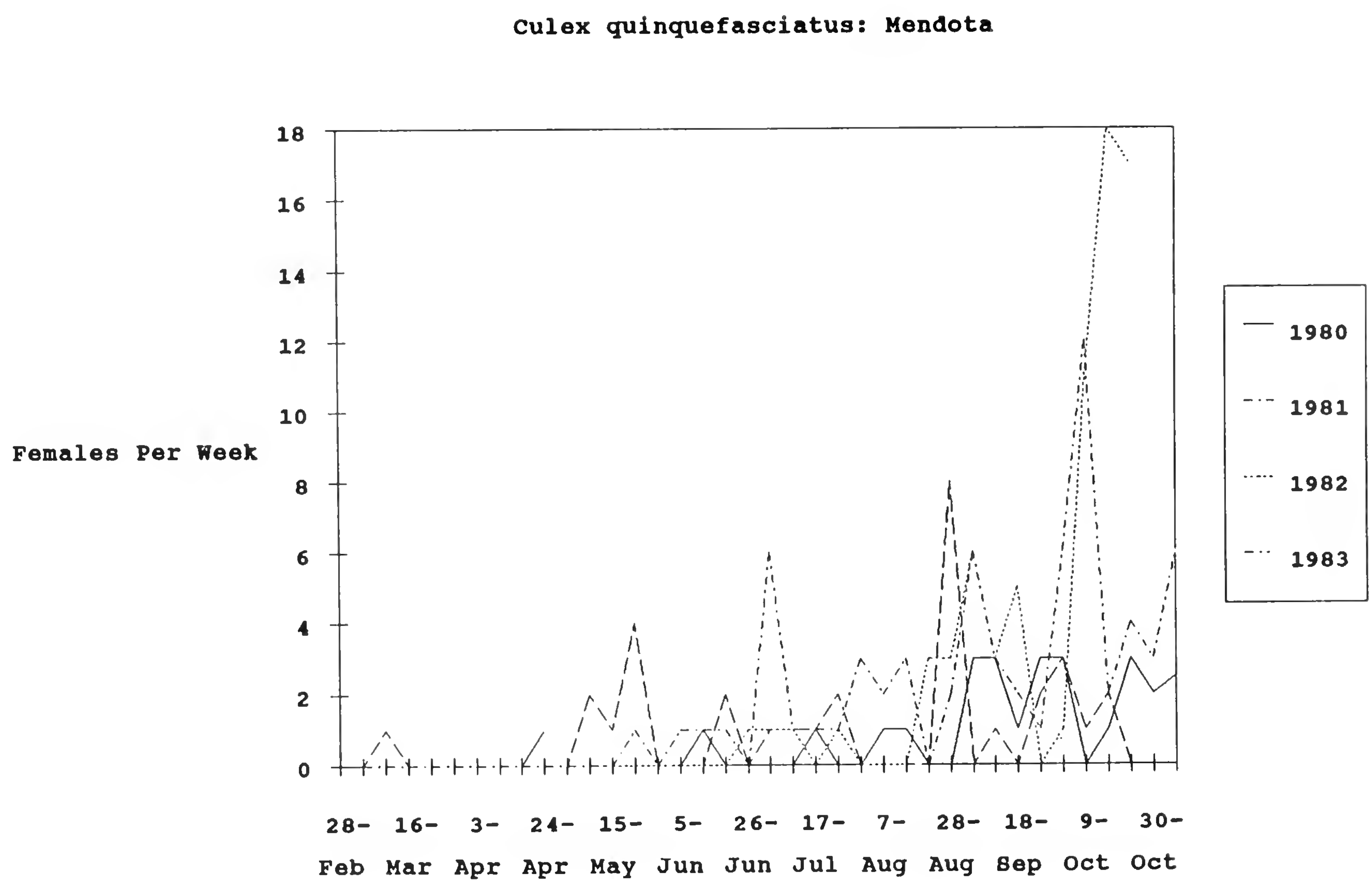


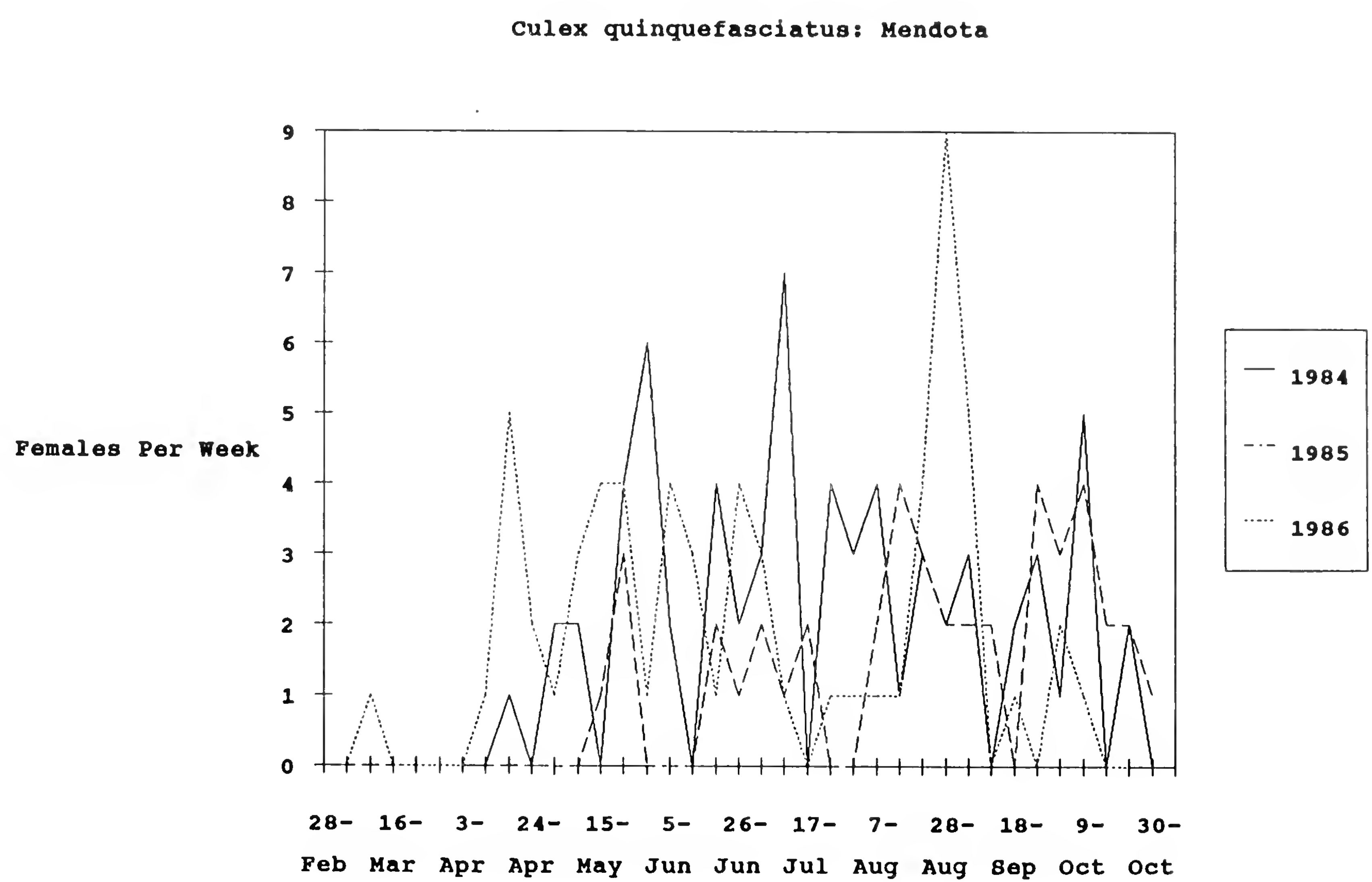
Culex quinquefasciatus: Firebaugh

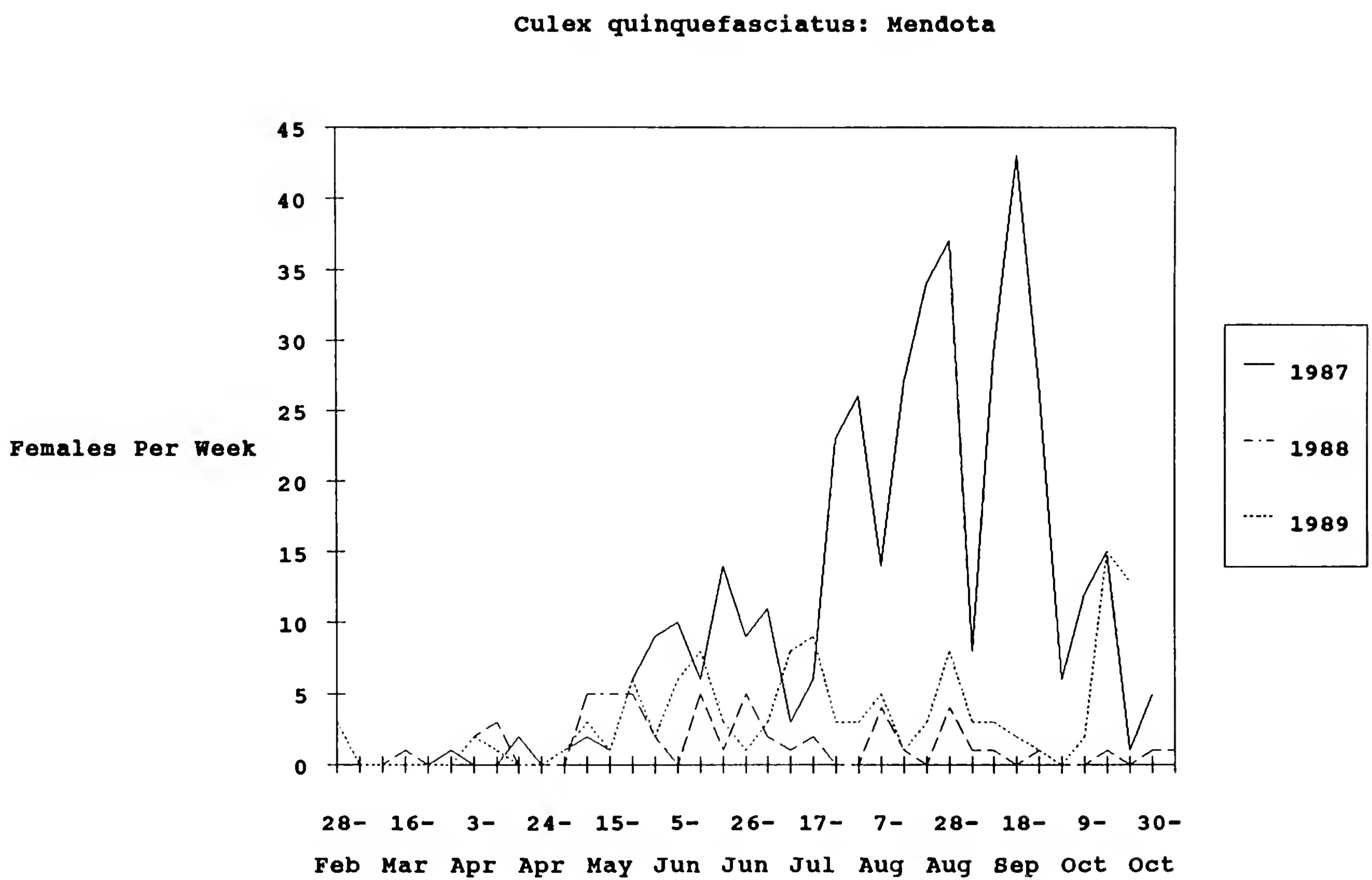


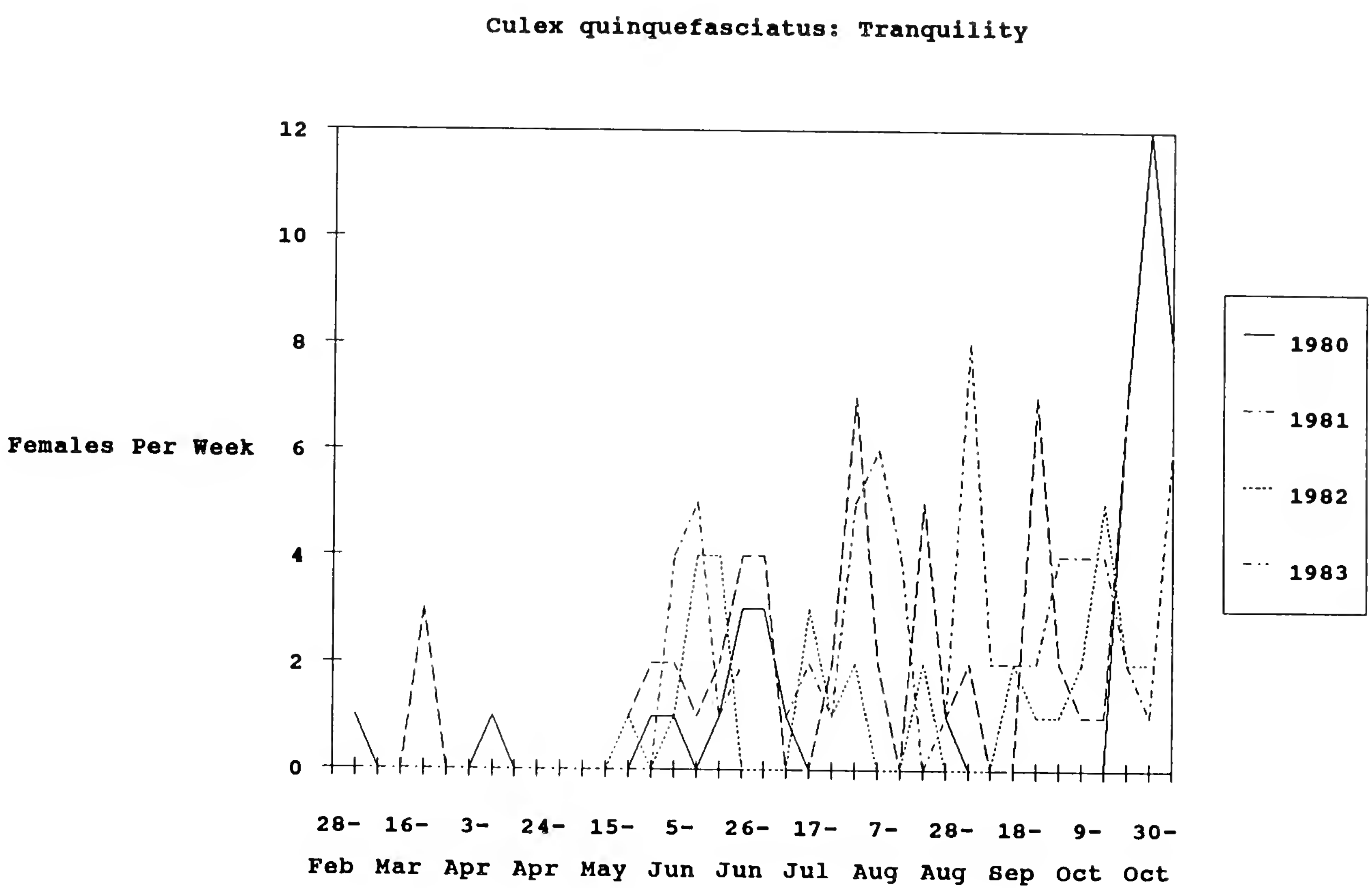
Culex quinquefasciatus: Firebaugh




Culex quinquefasciatus: Mendota
Females Per Week
18
16
14
12
10
8
6
4
2
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1980
1981
1982
1983

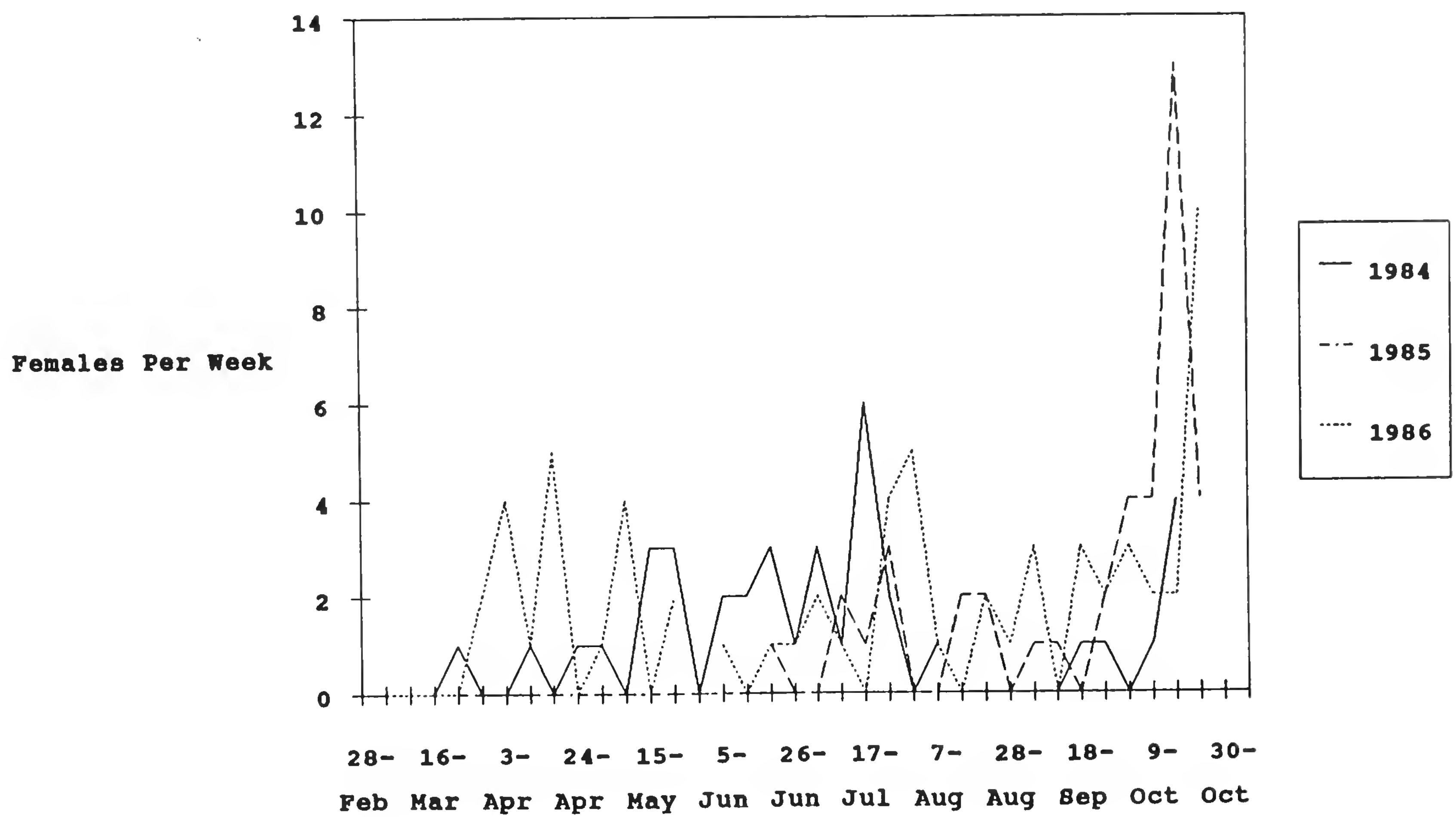

Culex quinquefasciatus: Mendota
Females Per Week
0
1
2
3
4
5
6
7
8
9
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986


Culex quinquefasciatus: Mendota
Females Per Week
45
40
35
30
25
20
15
10
5
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1987
1988
1989

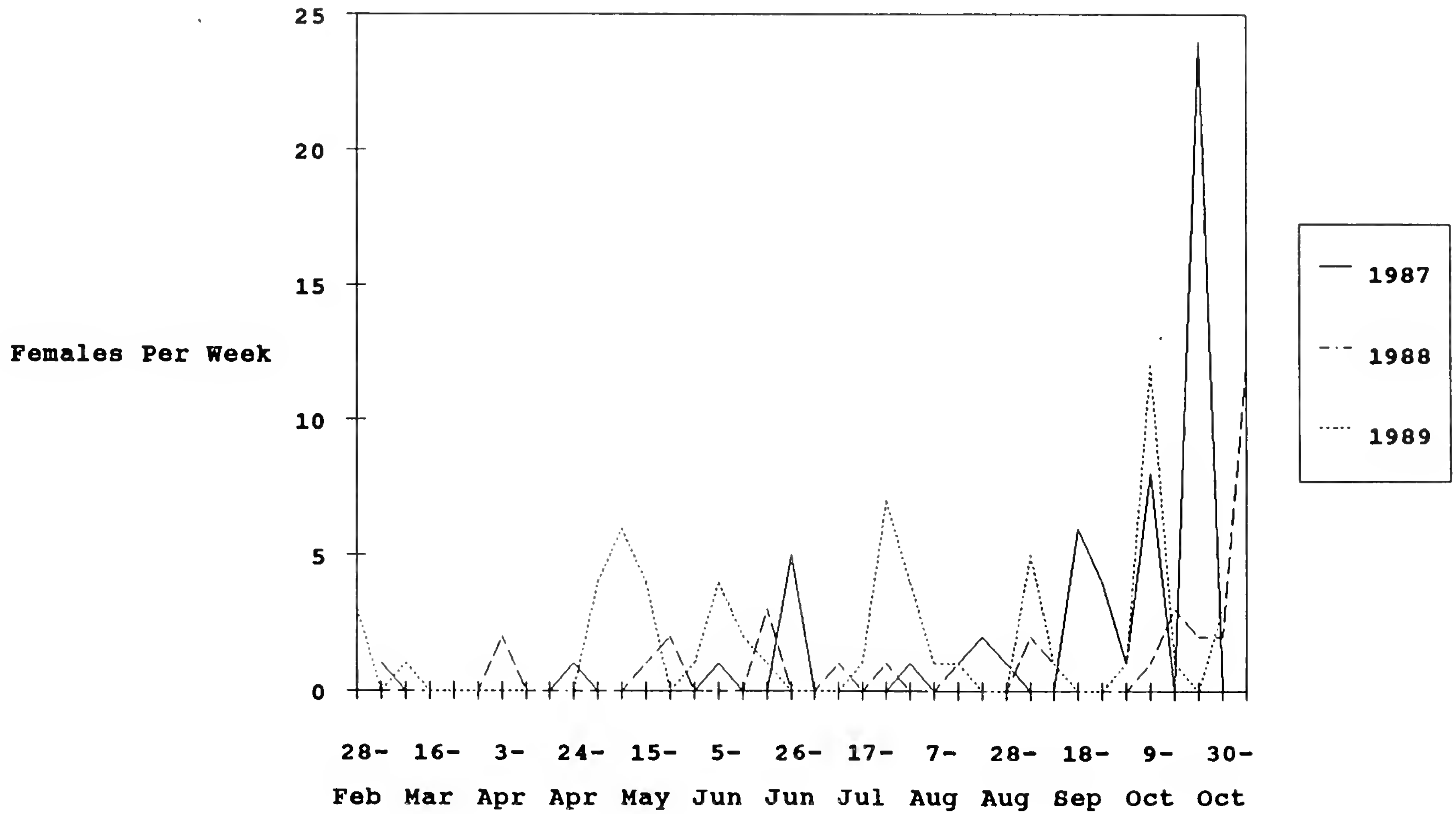


Culex quinquefasciatus: Tranquility
Females Per Week
0
2
4
6
8
10
12
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1980
1981
1982
1983

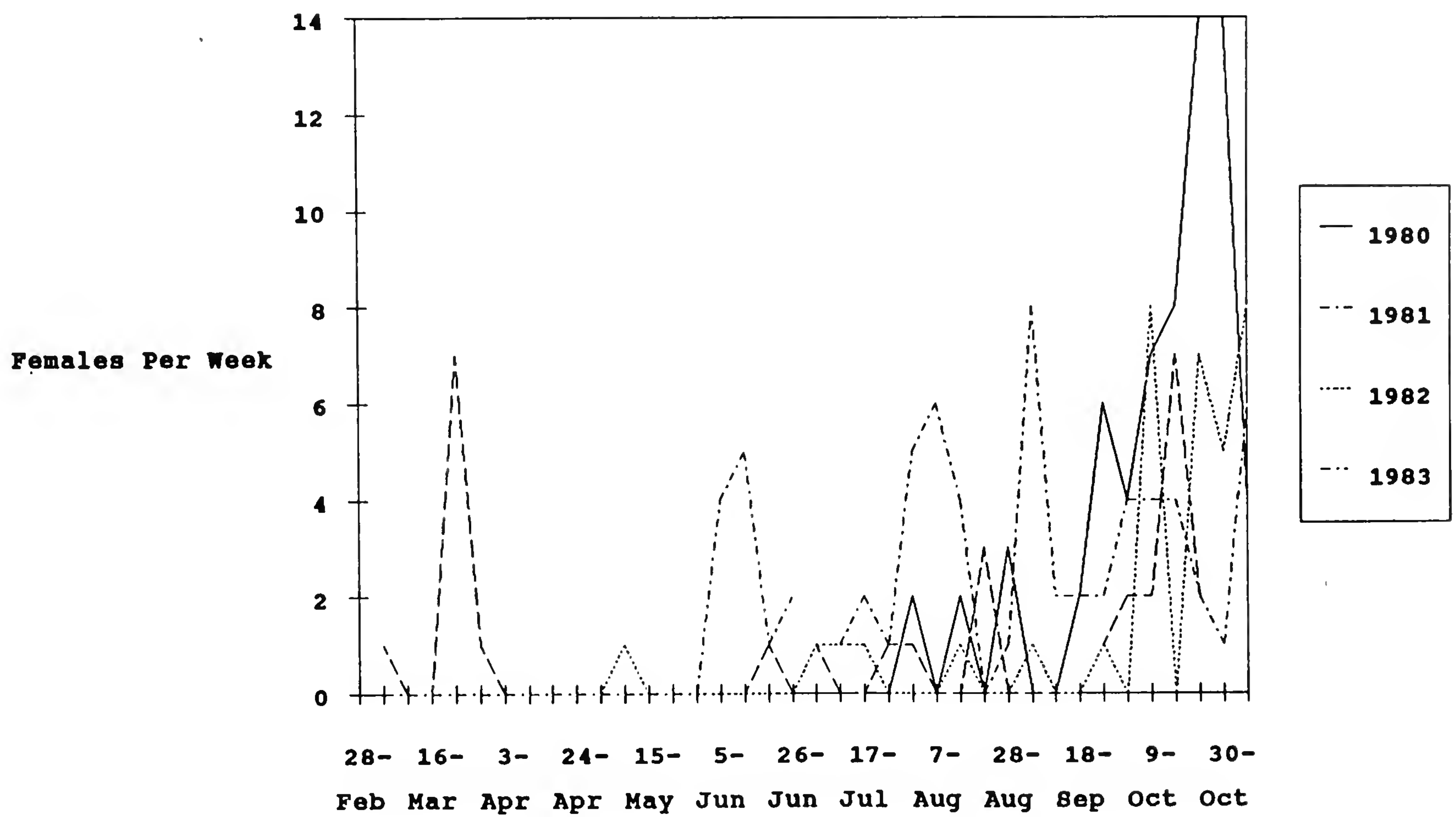
Culex quinquefasciatus: Tranquility



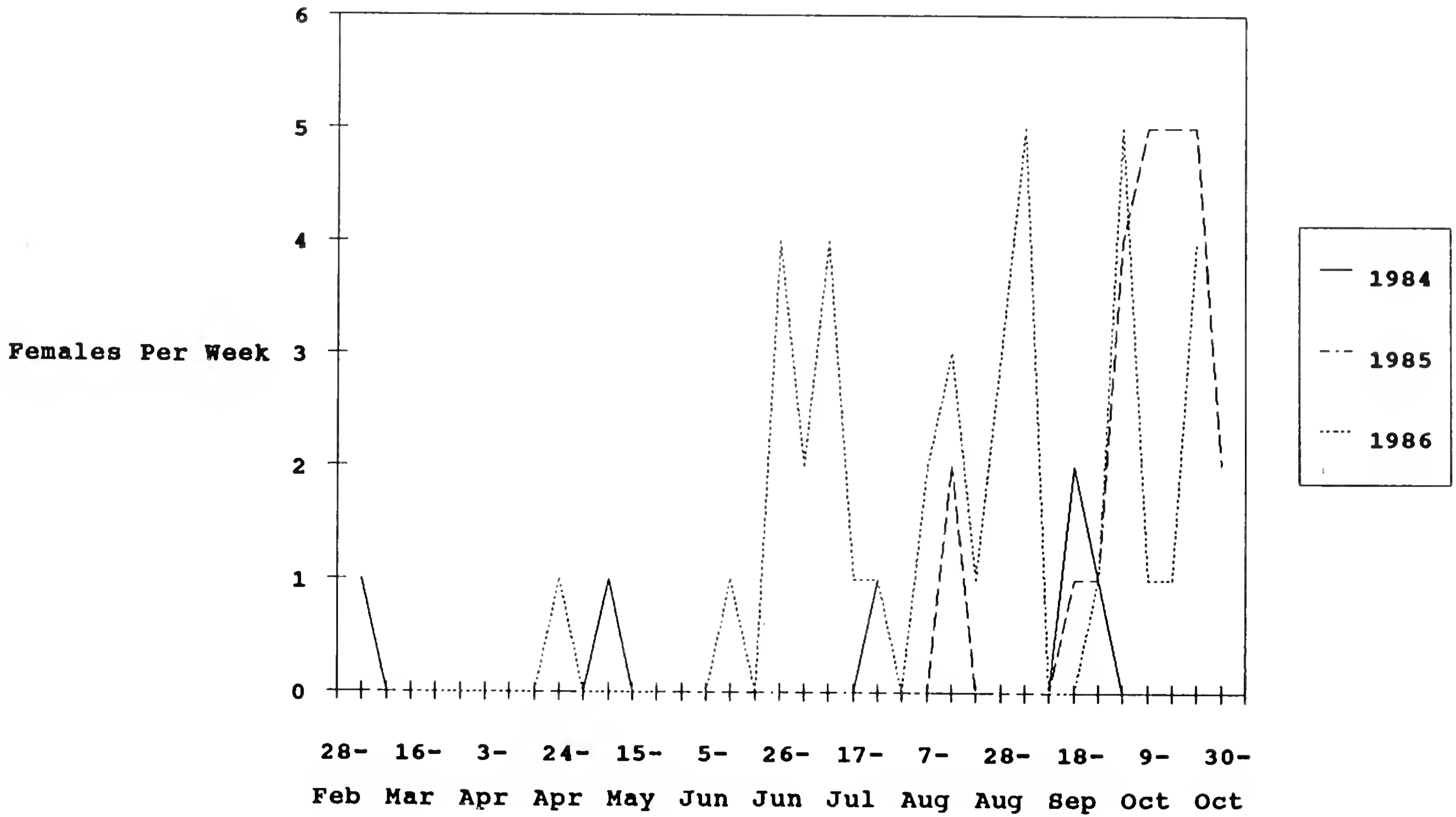
Culex quinquefasciatus: Tranquility



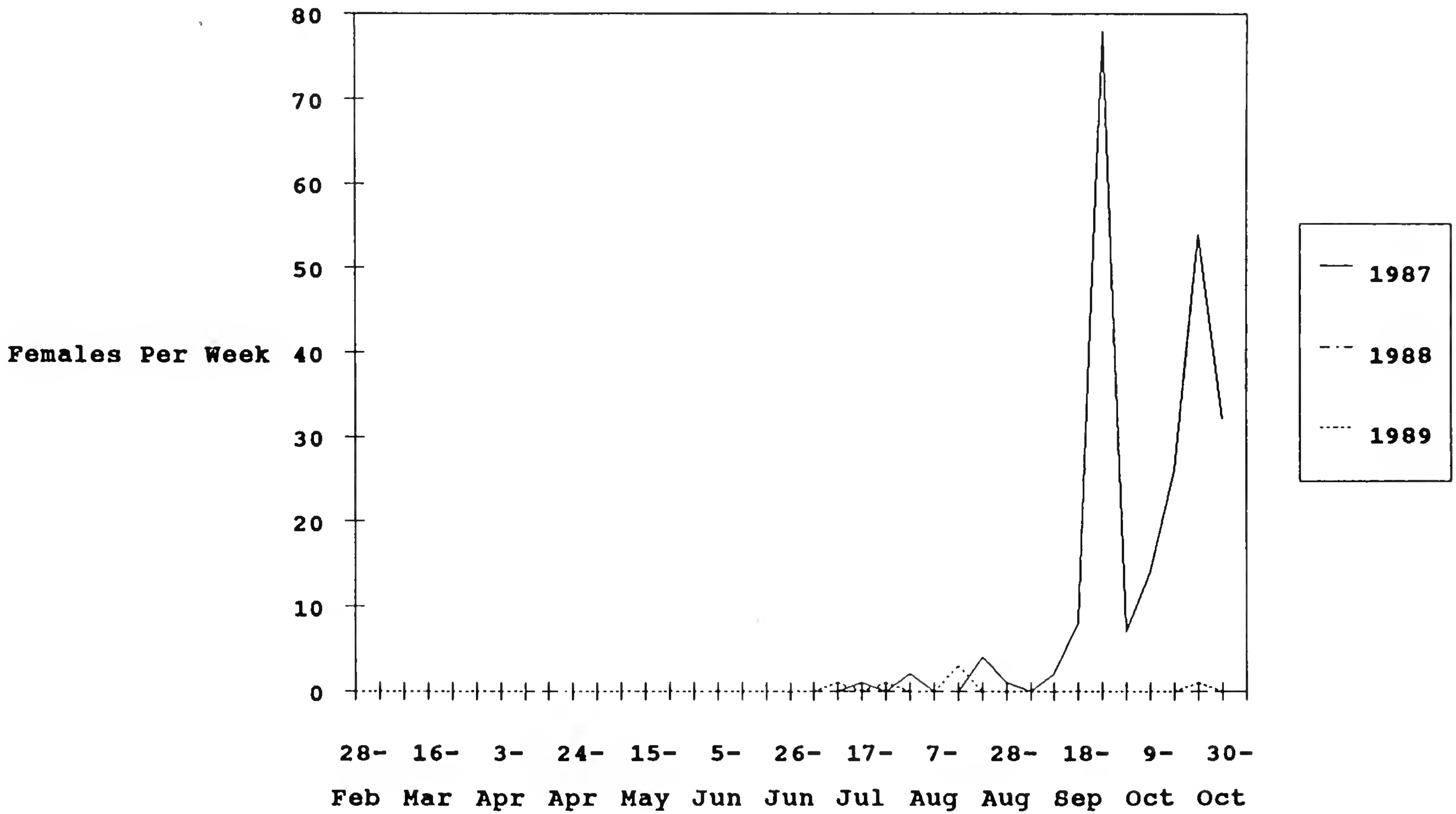
Culex quinquefasciatus: Canuta



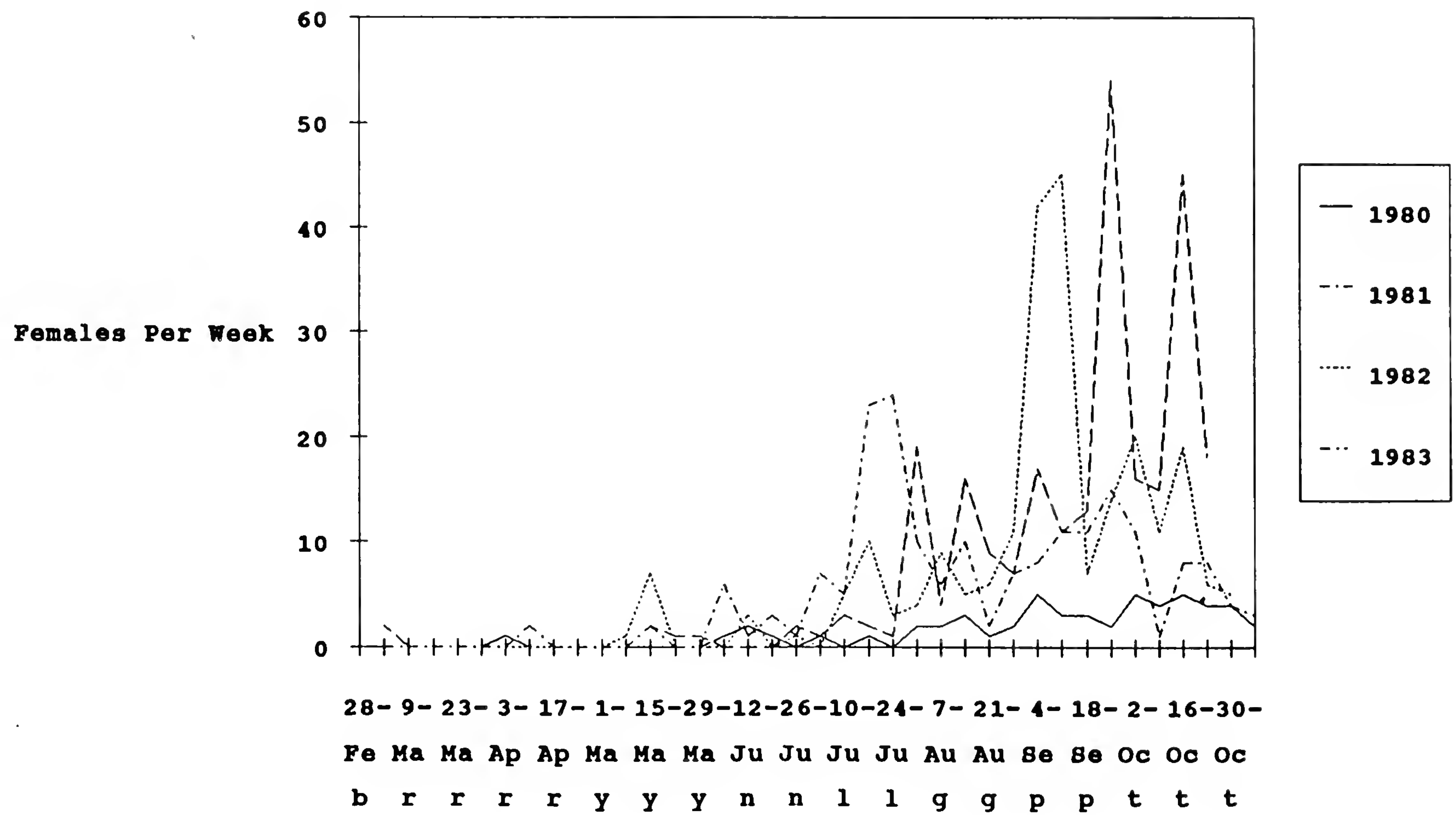
Culex quinquefasciatus: Canuta

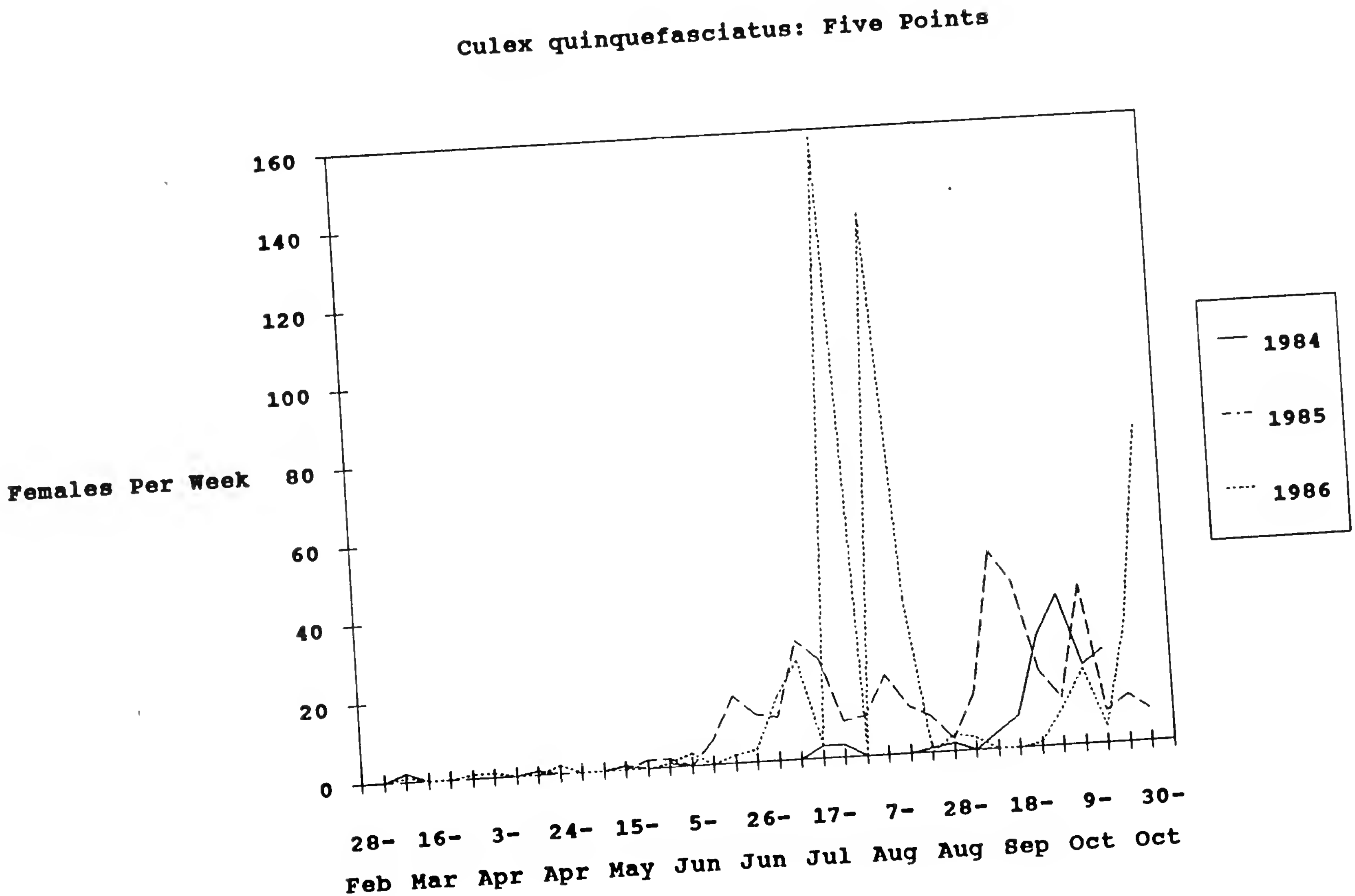


Culex quinquefasciatus: Canuta

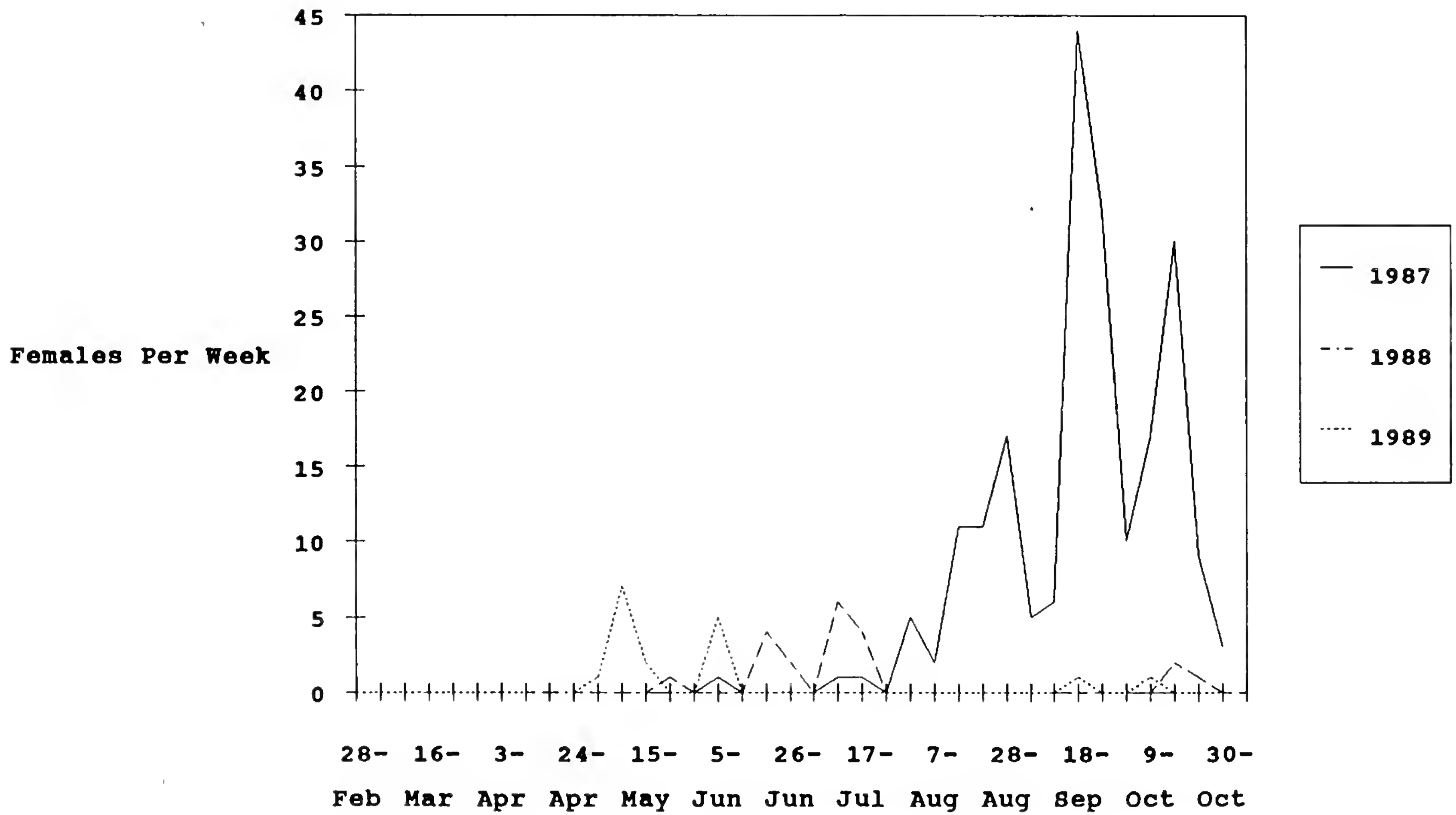


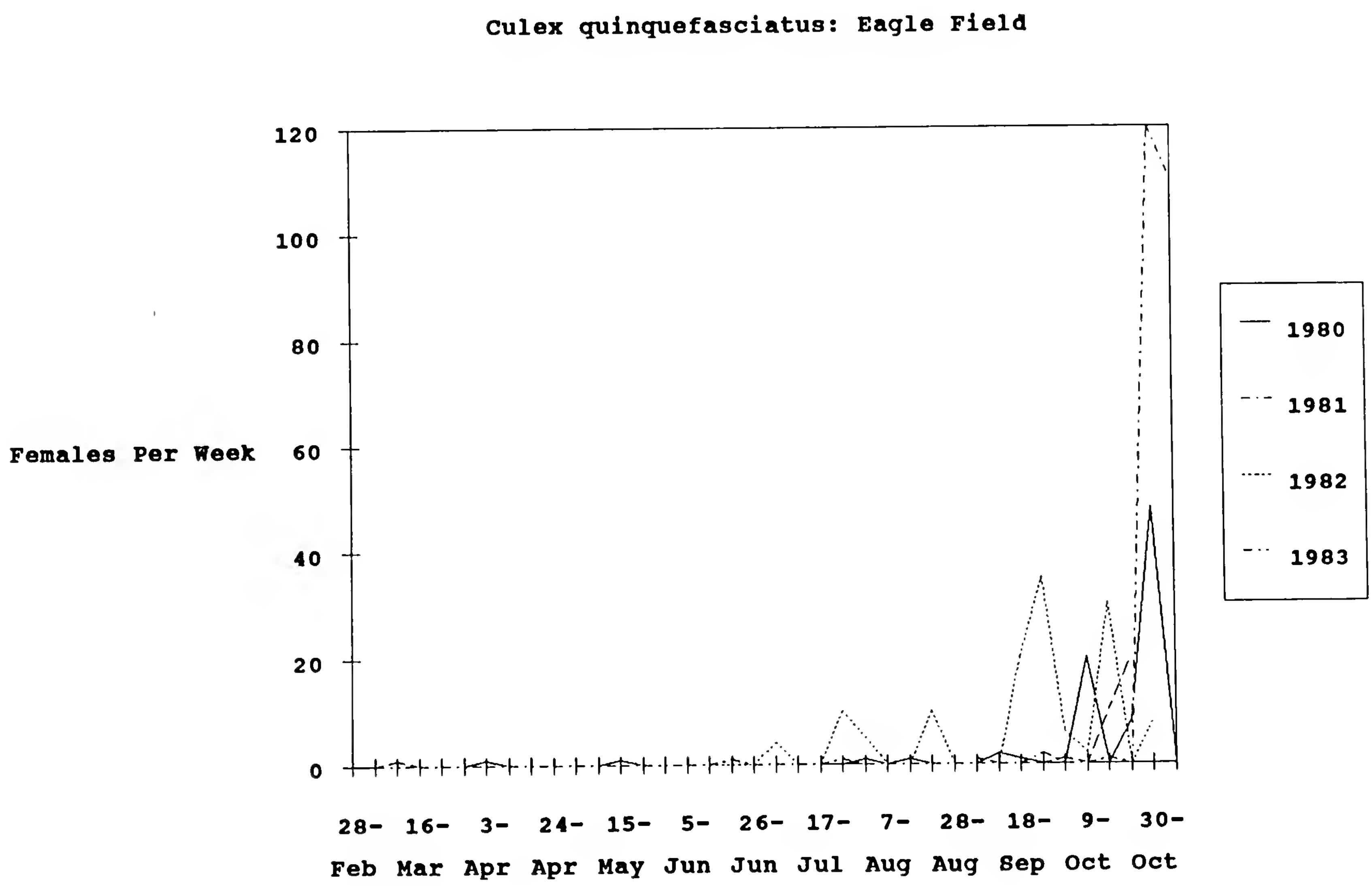
Culex quinquefasciatus: Five Points



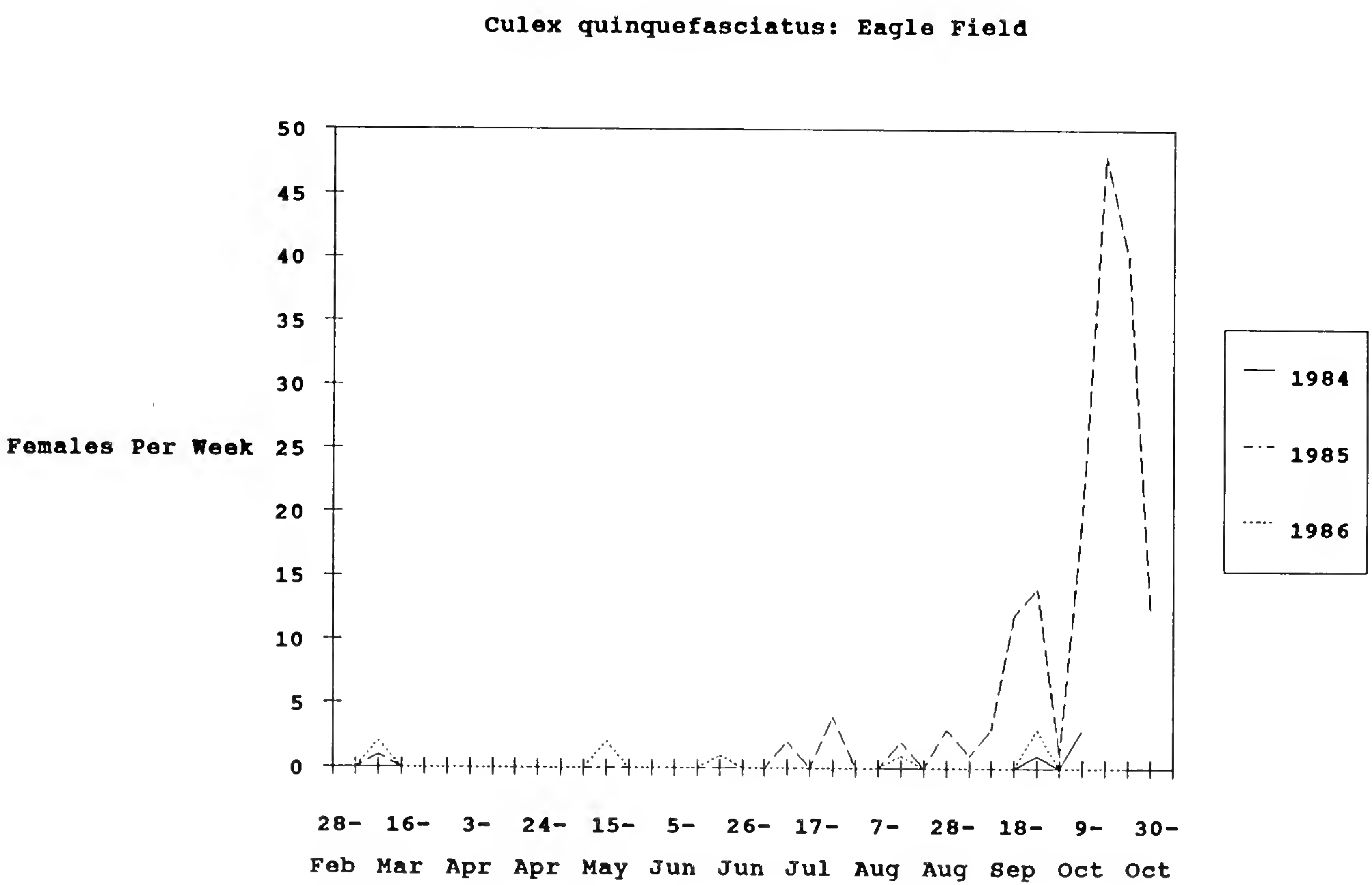

Culex quinquefasciatus: Five Points
Females Per Week
0
20
40
60
80
100
120
140
160
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

Culex quinquefasciatus: Five Points

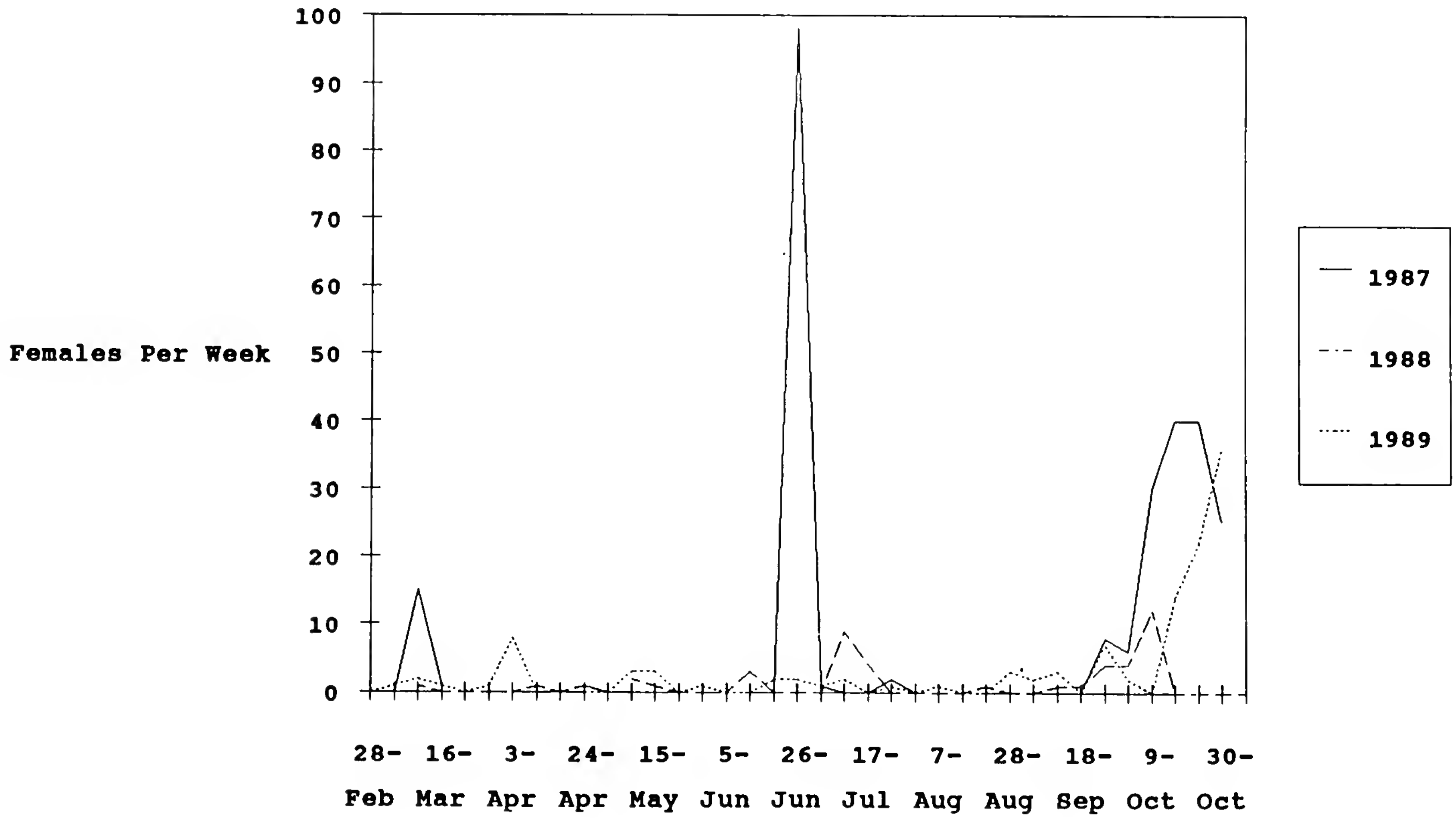




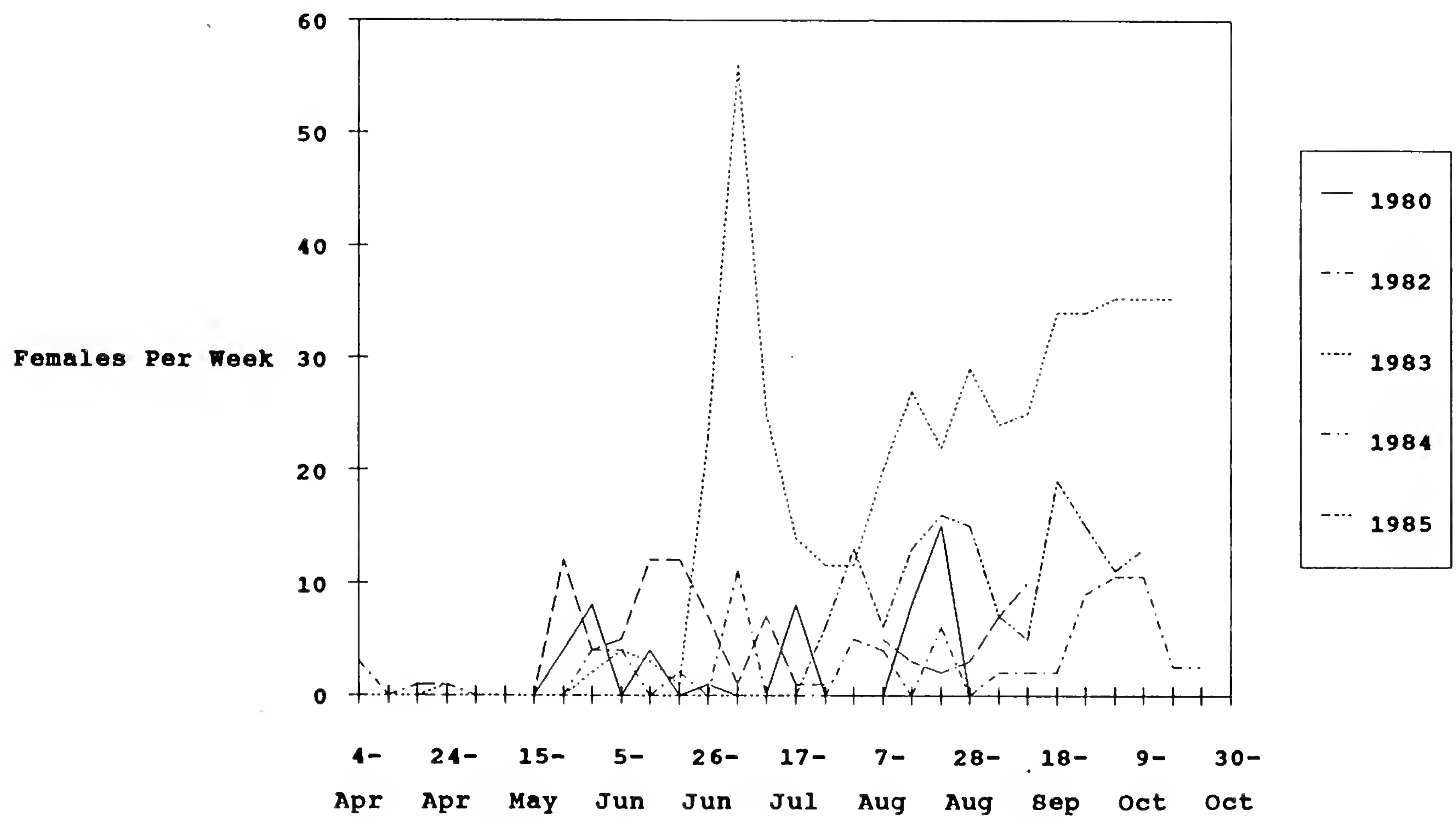
Culex quinquefasciatus: Eagle Field
Females Per Week
0
20
40
60
80
100
120
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1980
1981
1982
1983


Culex quinquefasciatus: Eagle Field
Females Per Week
0
5
10
15
20
25
30
35
40
45
50
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1984
1985
1986

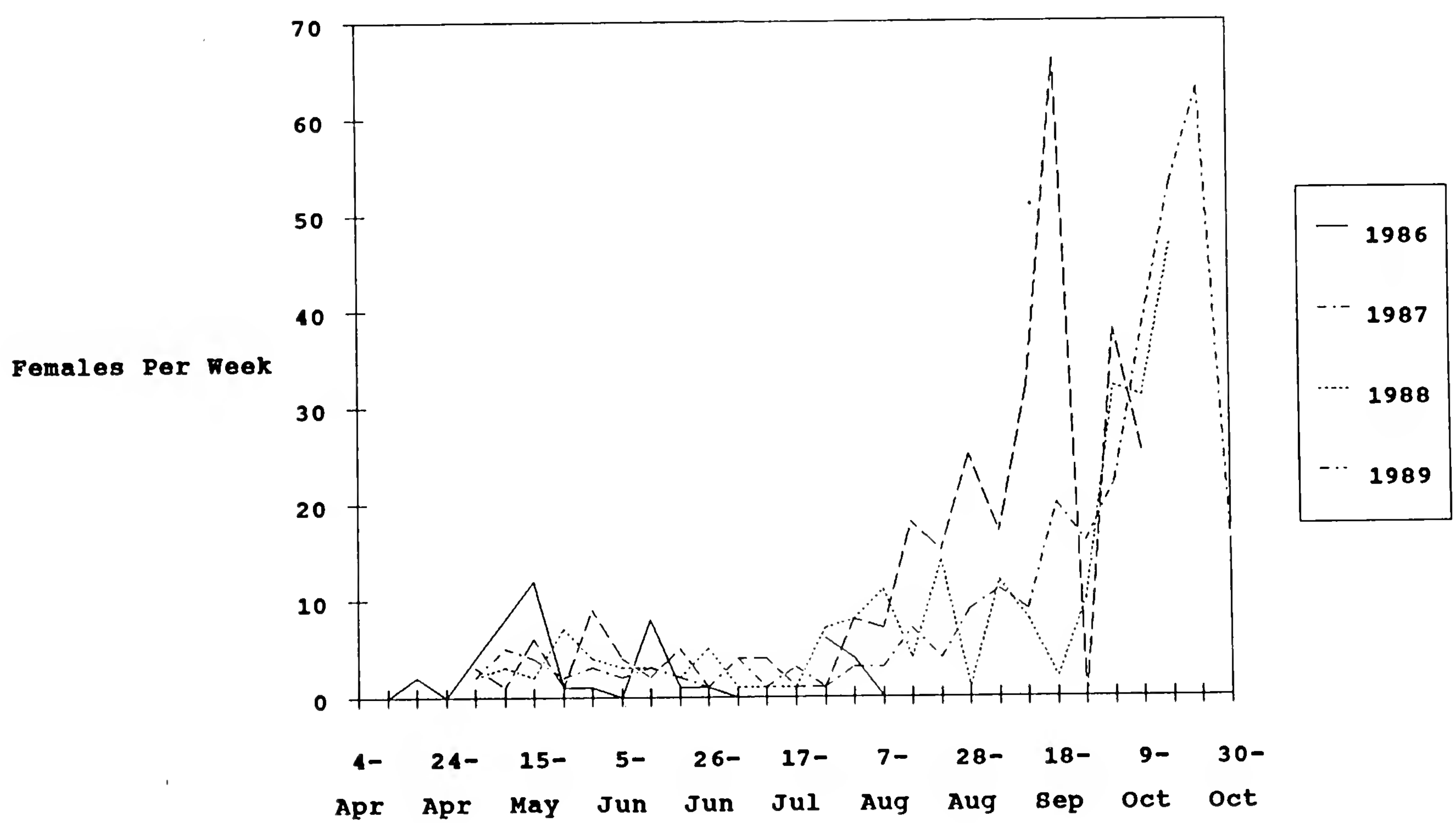
Culex quinquefasciatus: Eagle Field



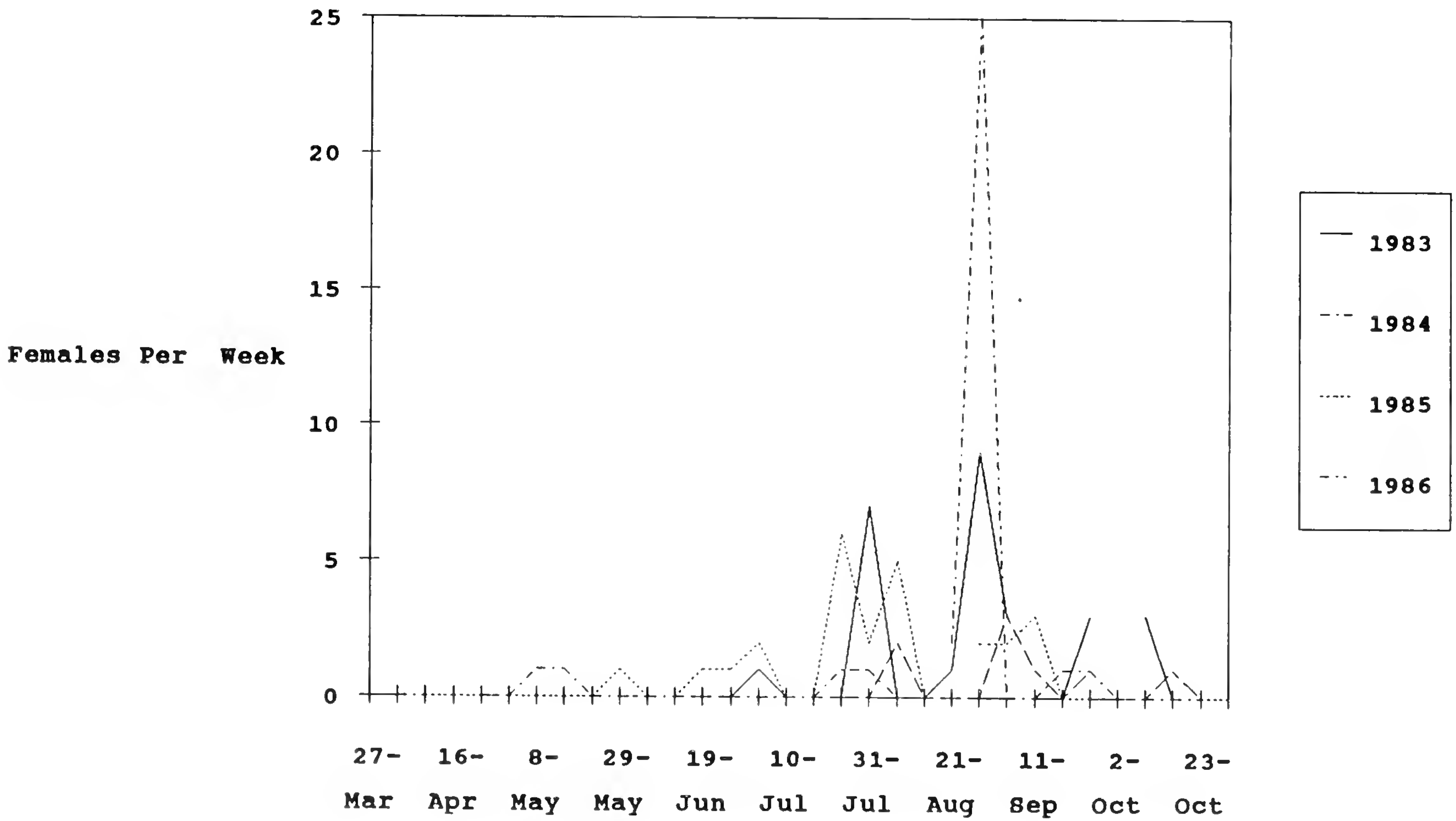
Culex quinquefasciatus: Stratford



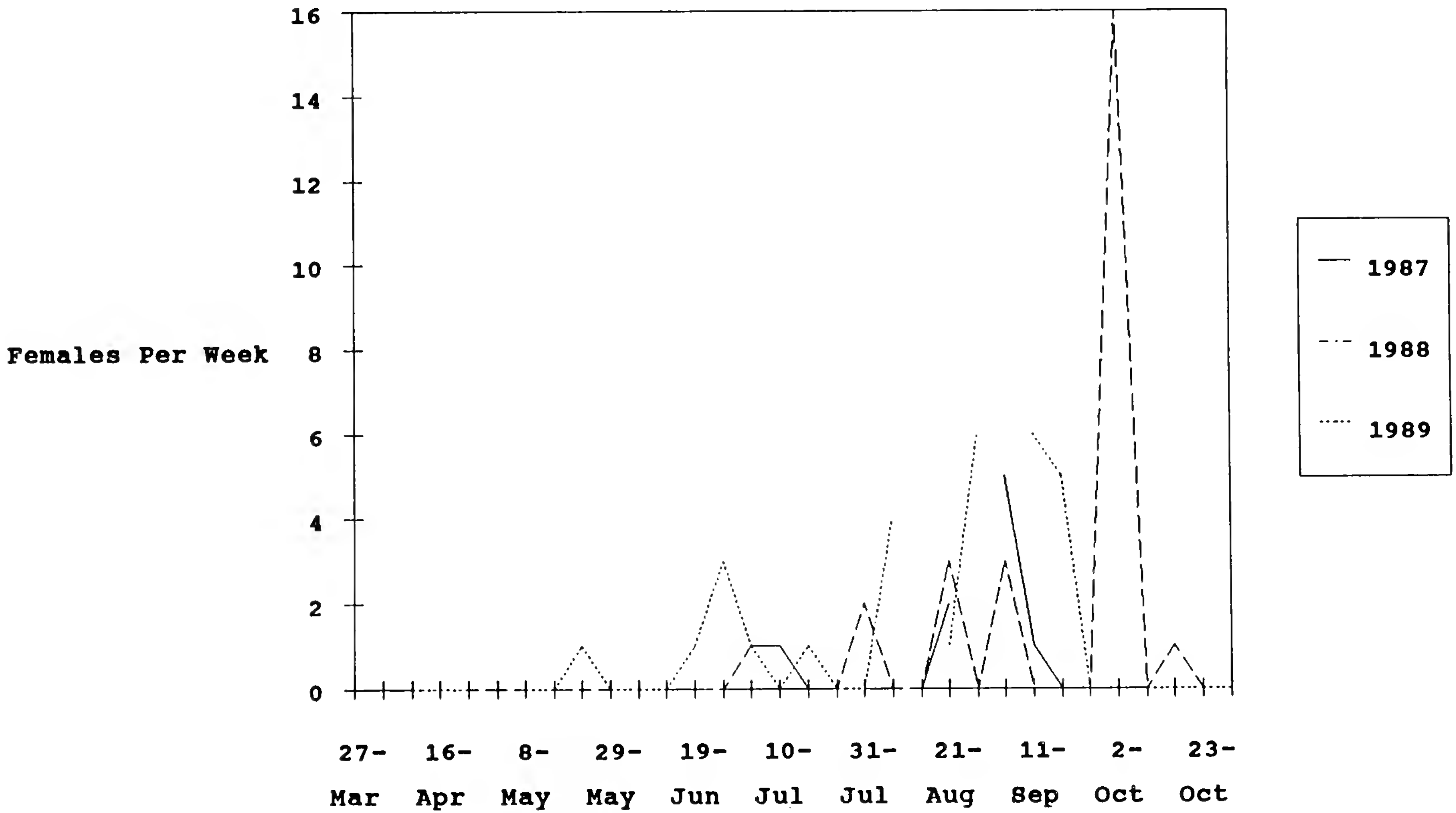
Culex quinquefasciatus: Stratford



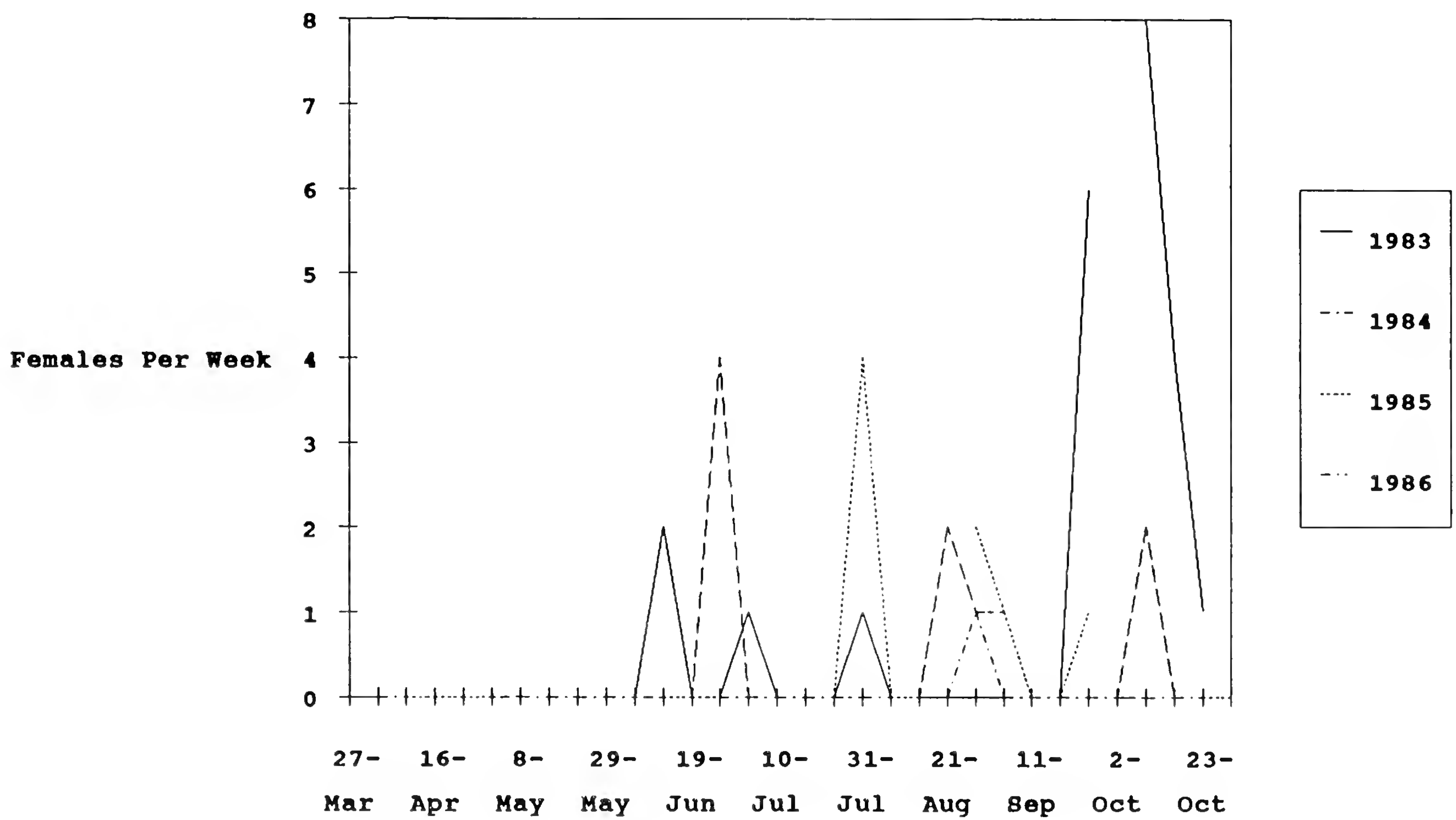
Aedes nigromaculis: Gustine

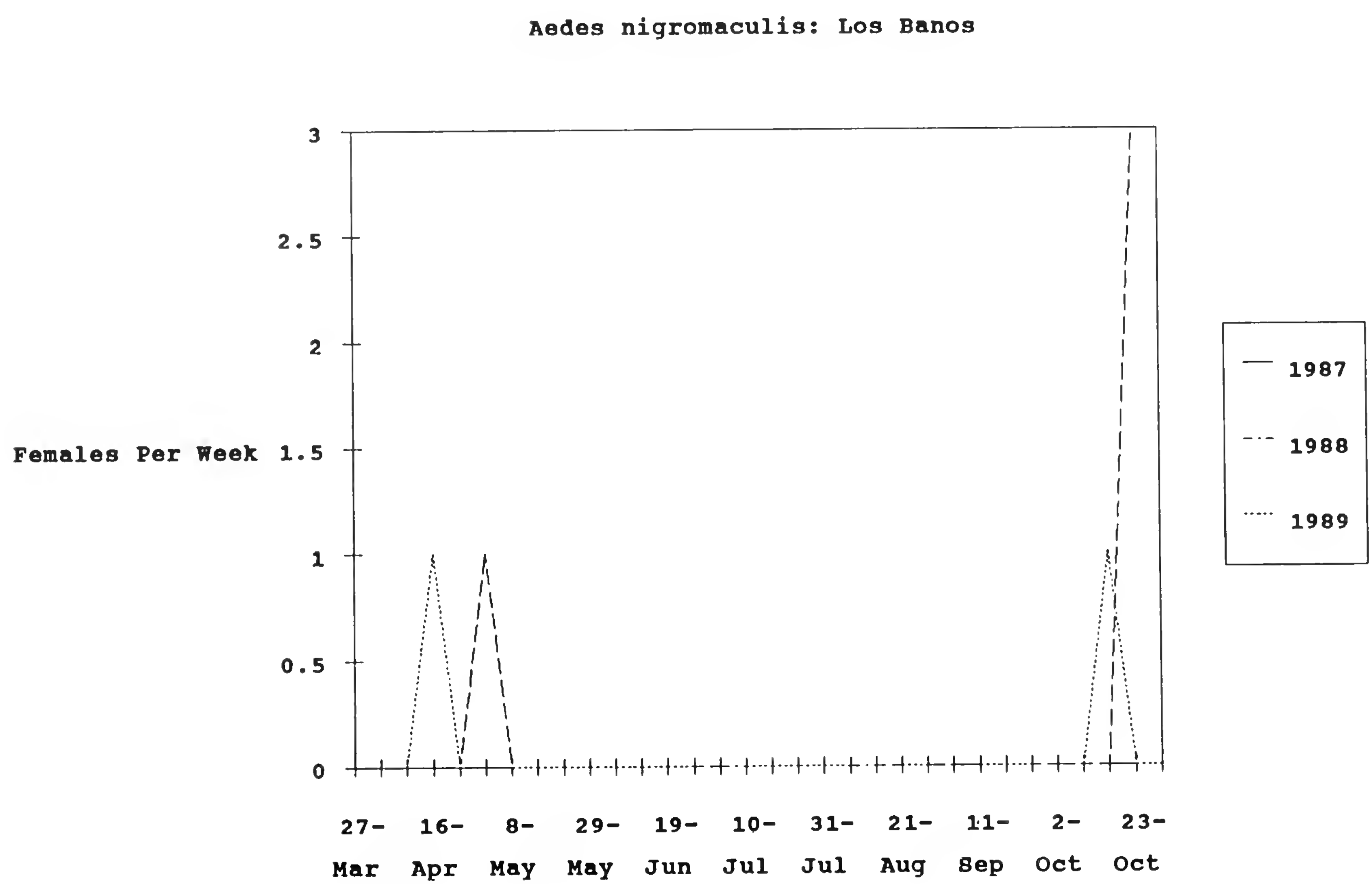


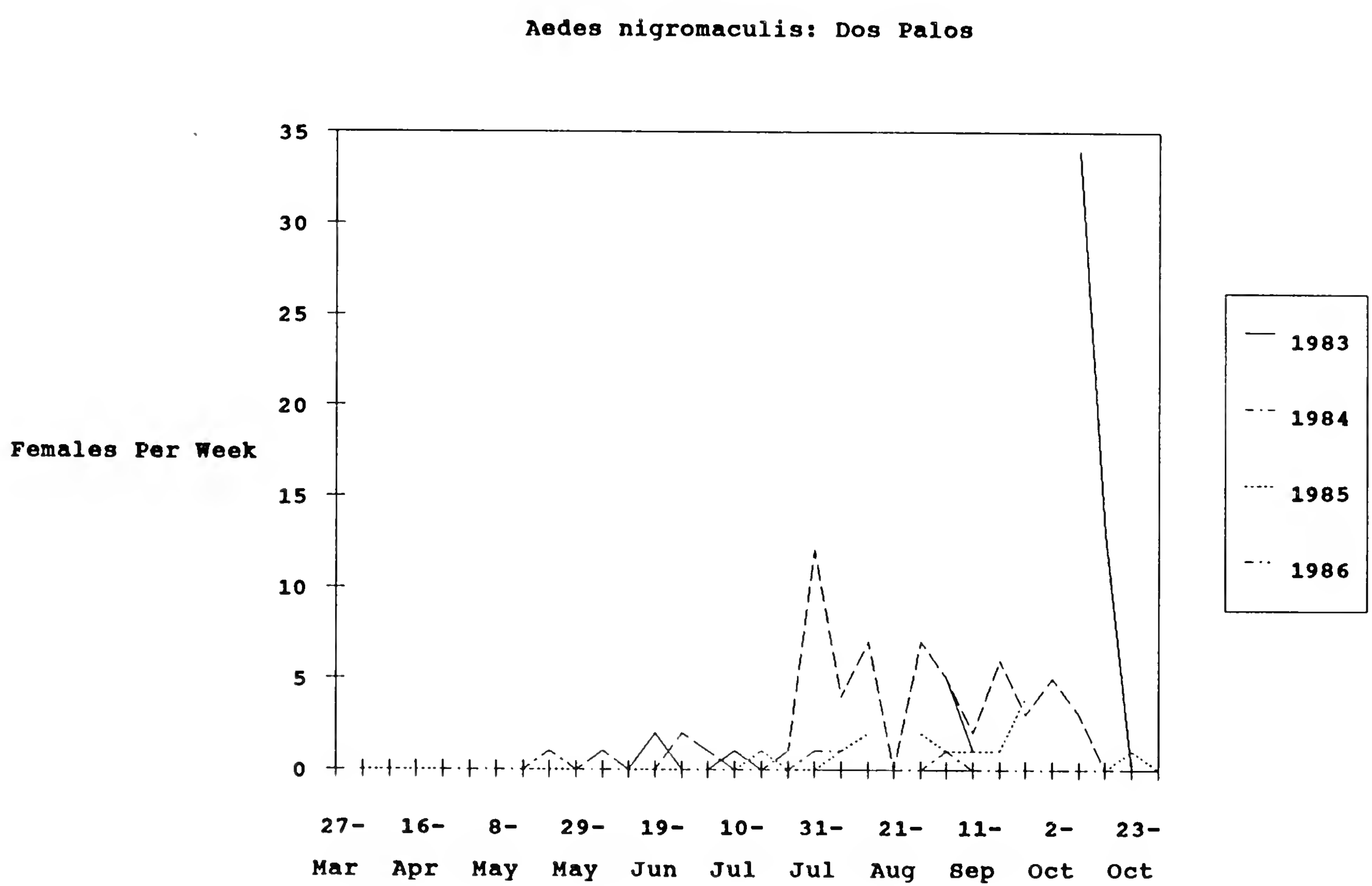
Aedes nigromaculis: Gustine

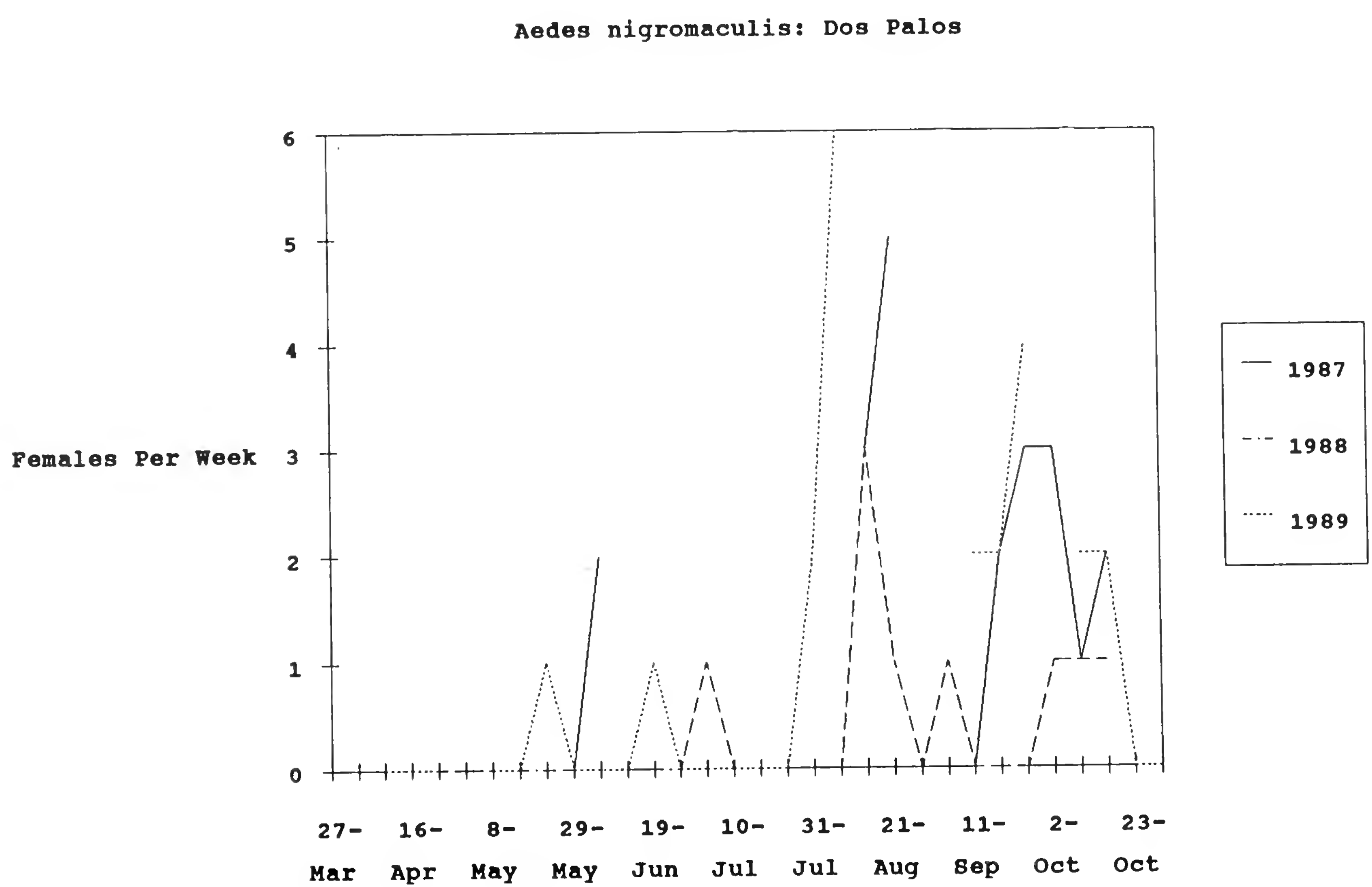


Aedes nigromaculis: Los Banos

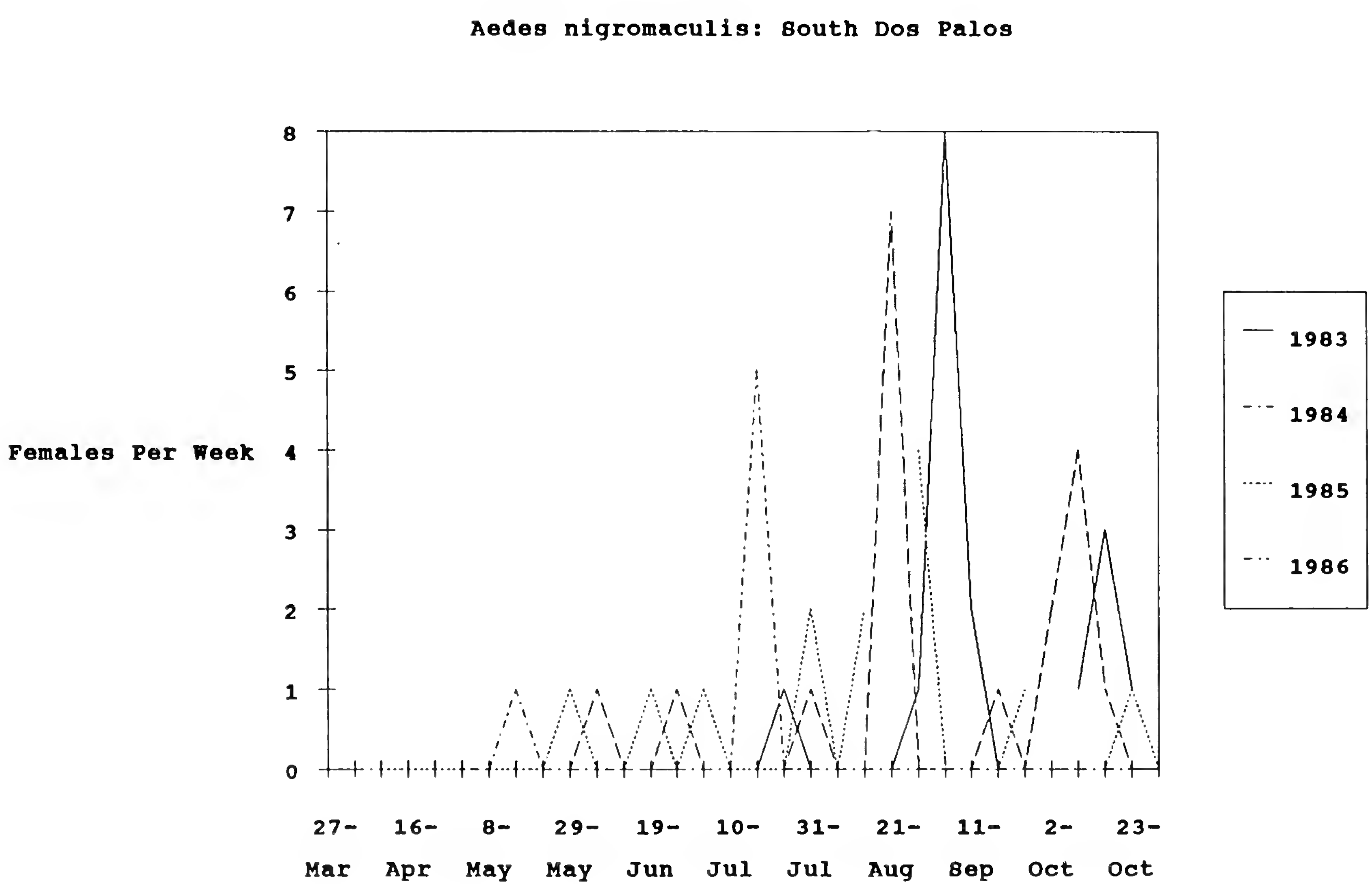


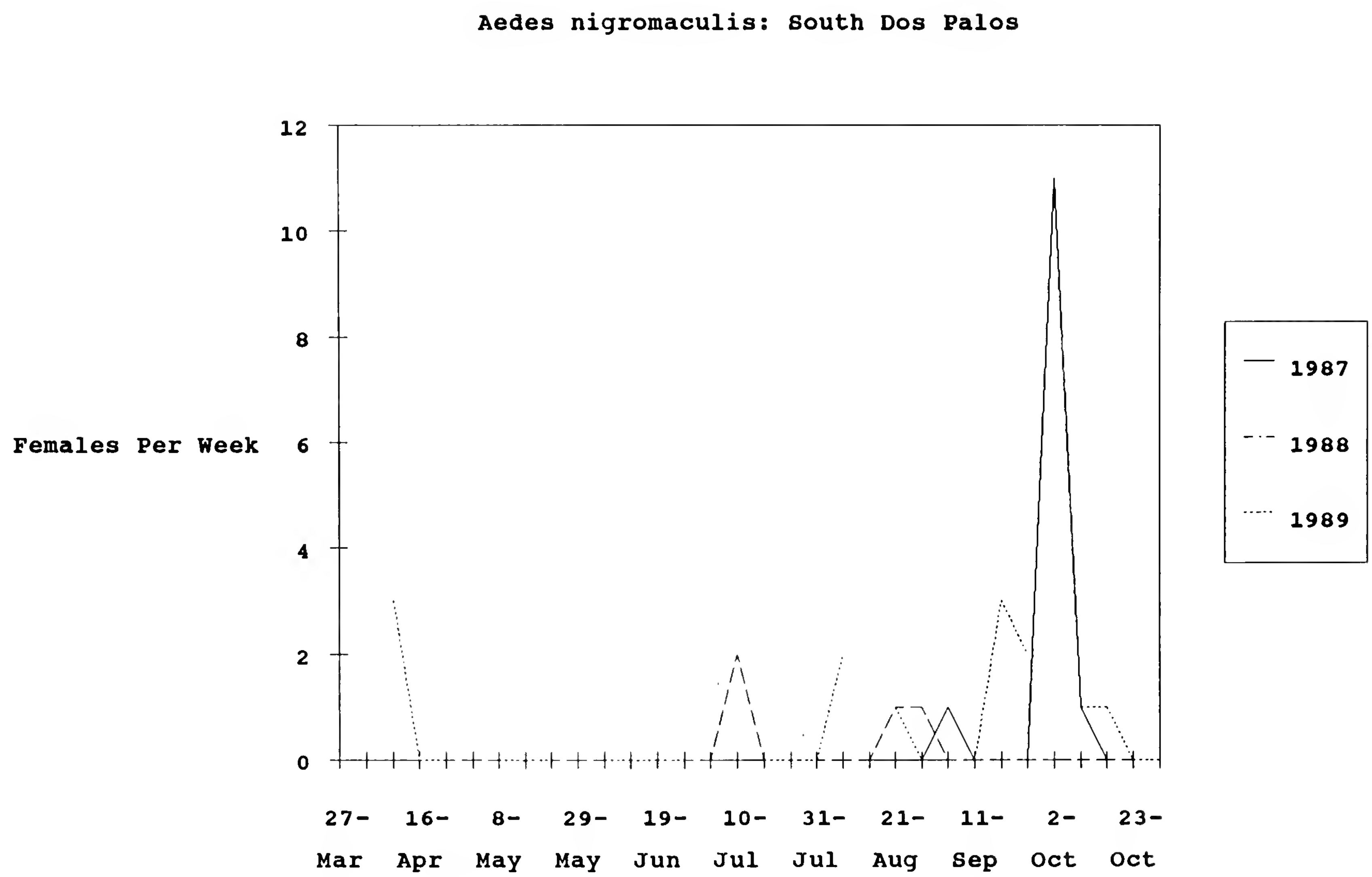

Aedes nigromaculis: Los Banos
Females Per Week
3
2.5
2
1.5
1
0.5
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

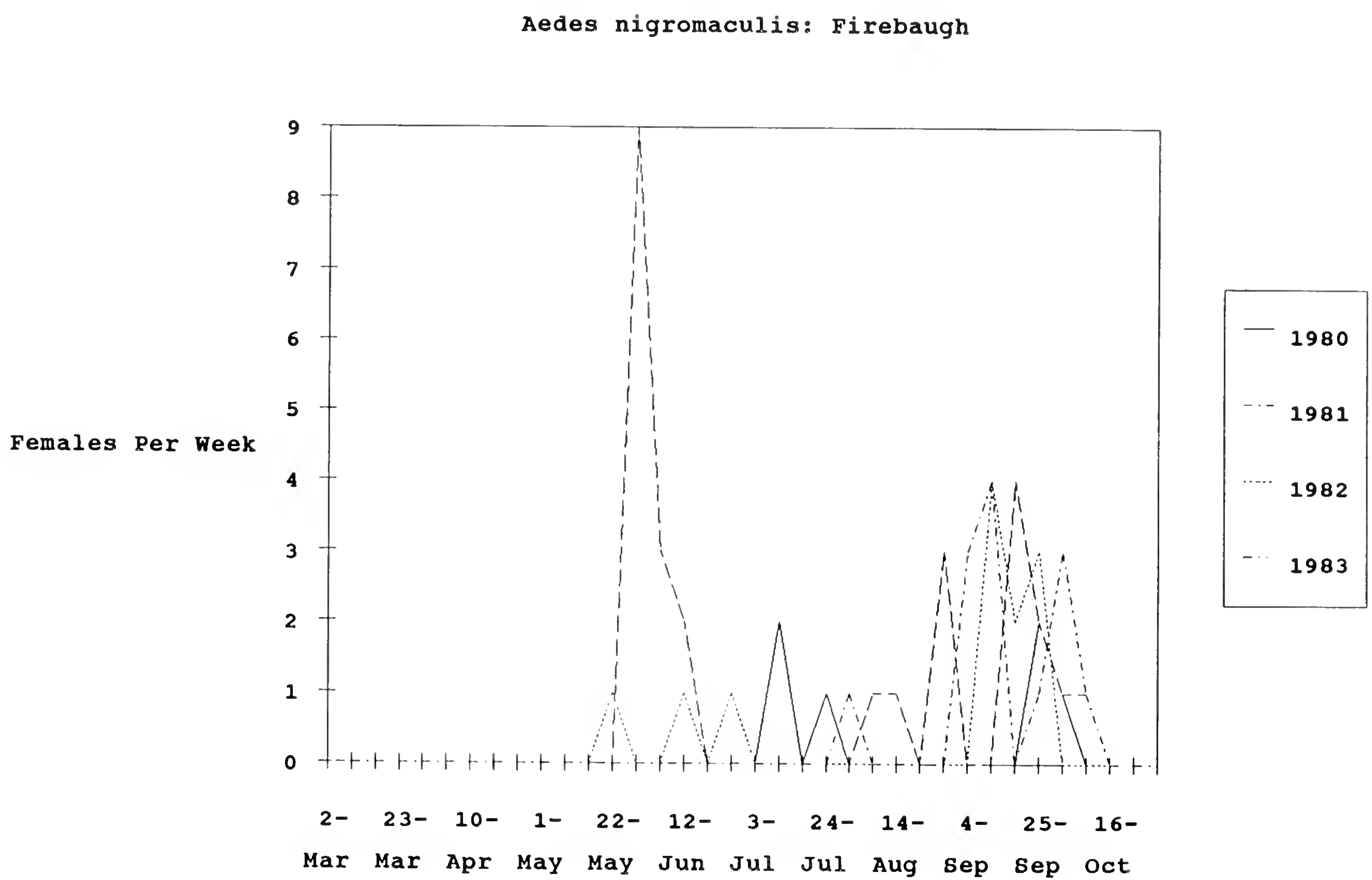

Aedes nigromaculis: Dos Palos
Females Per Week
35
30
25
20
15
10
5
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1983
1984
1985
1986



Aedes nigromaculis: Dos Palos
Females Per Week
0
1
2
3
4
5
6
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989

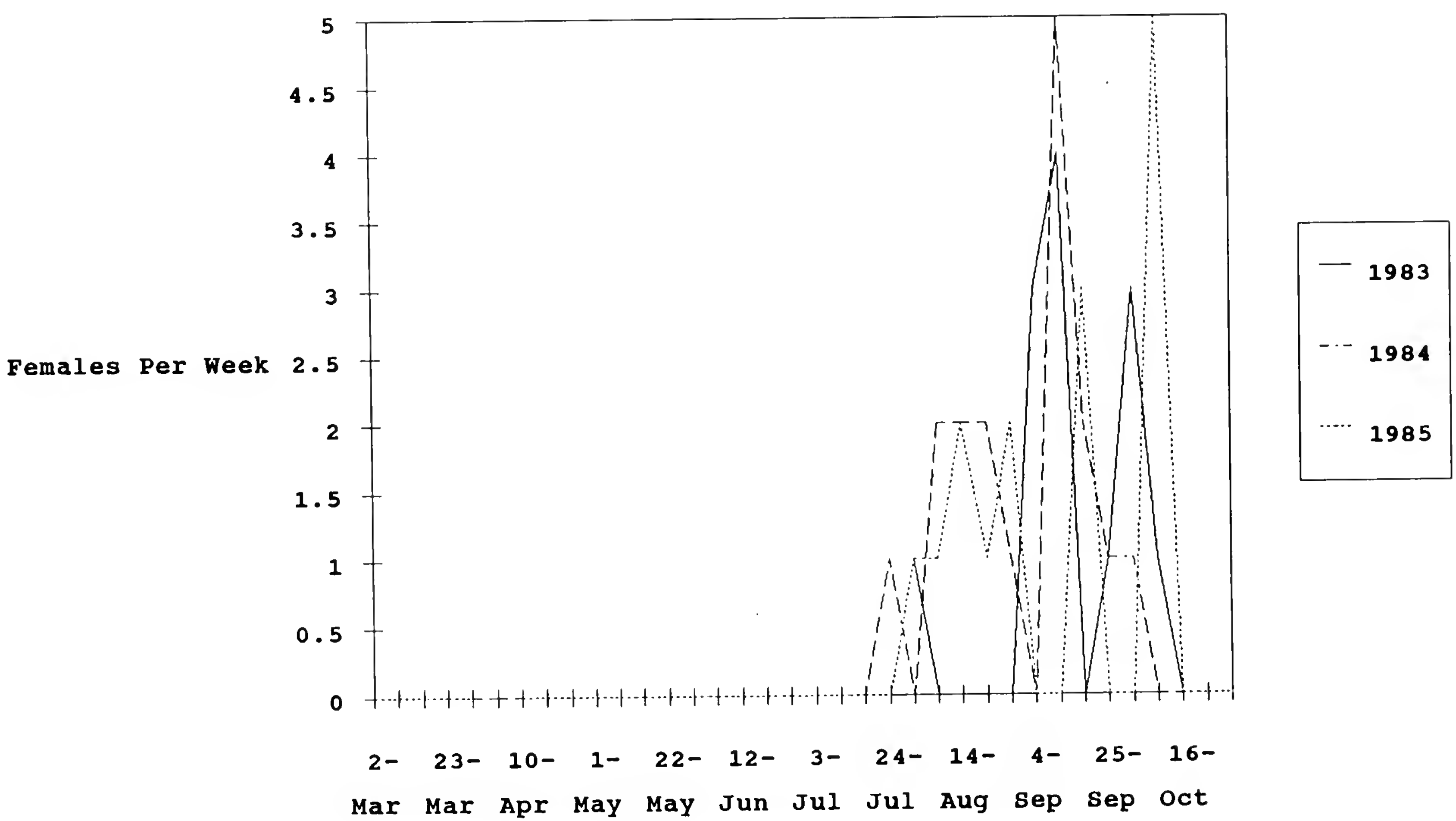

Aedes nigromaculis: South Dos Palos
Females Per Week
0
1
2
3
4
5
6
7
8
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1983
1984
1985
1986

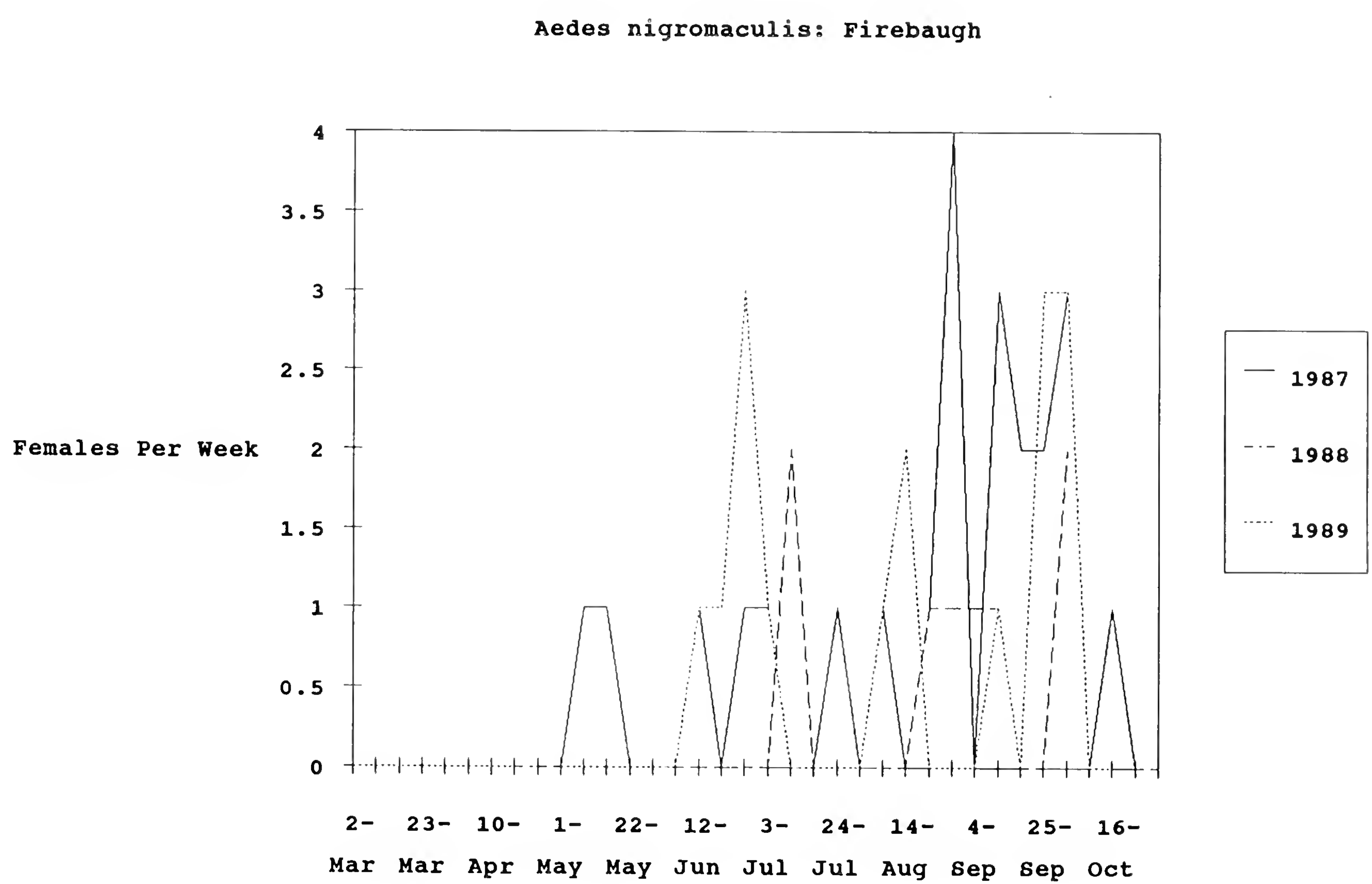

Aedes nigromaculis: South Dos Palos
Females Per Week
12
10
8
6
4
2
0
27- Mar
16- Apr
8- May
29- May
19- Jun
10- Jul
31- Jul
21- Aug
11- Sep
2- Oct
23- Oct
1987
1988
1989



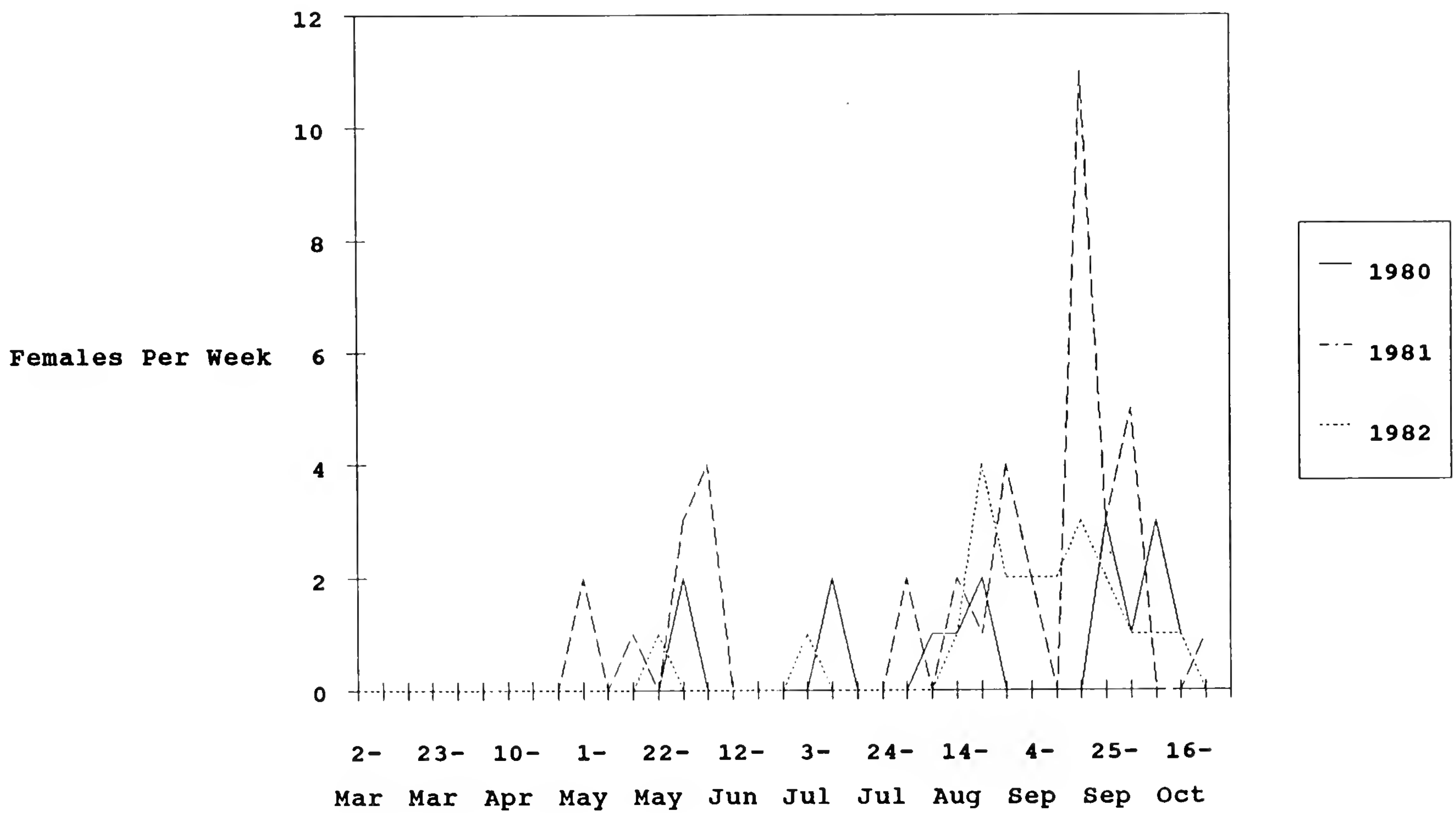
Aedes nigromaculis: Firebaugh
Females Per Week
0
1
2
3
4
5
6
7
8
9
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1980
1981
1982
1983

Aedes nigromaculsi: Firebaugh

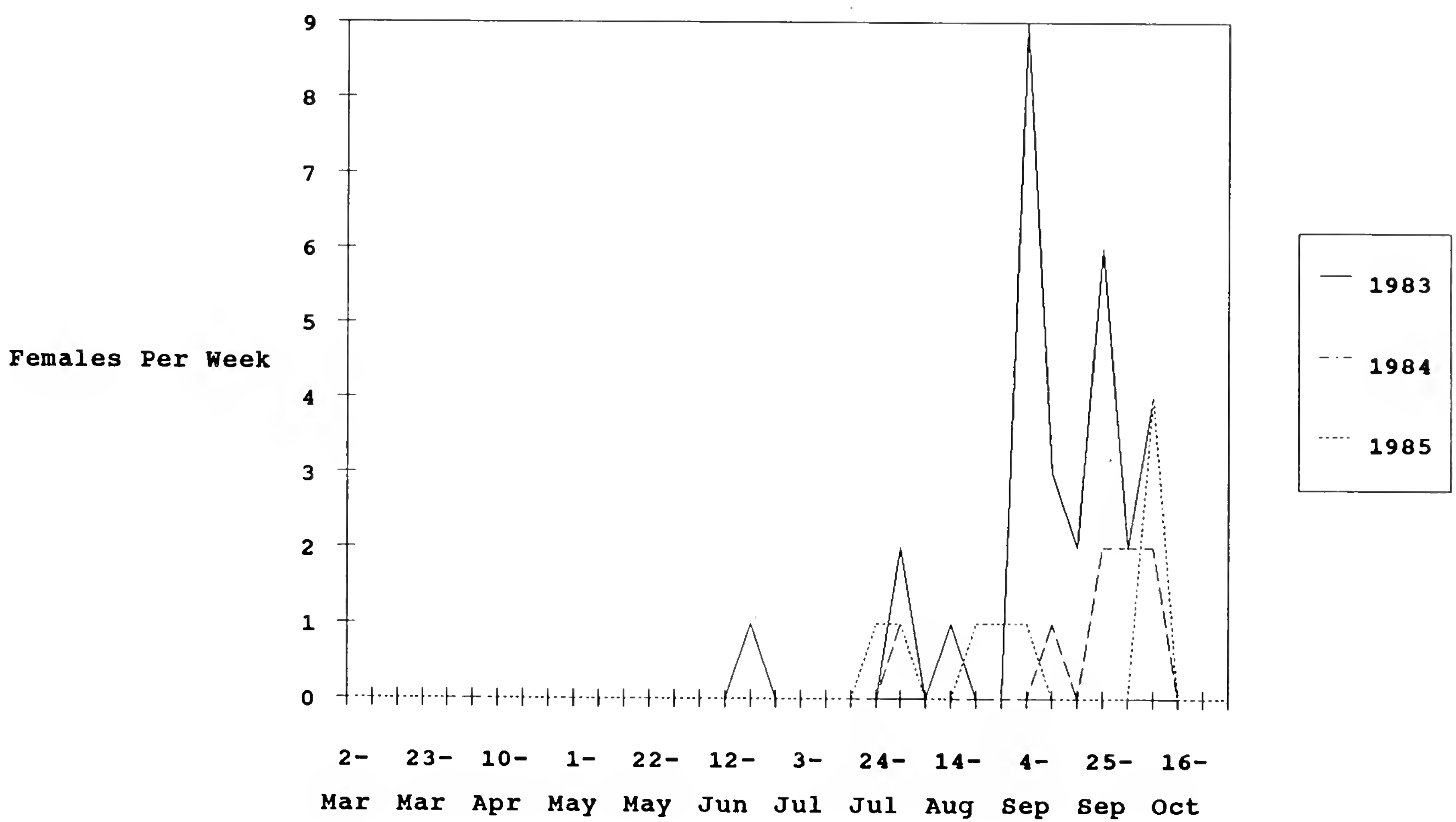



Aedes nigromaculis: Firebaugh
Females Per Week
4
3.5
3
2.5
2
1.5
1
0.5
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1987
1988
1989

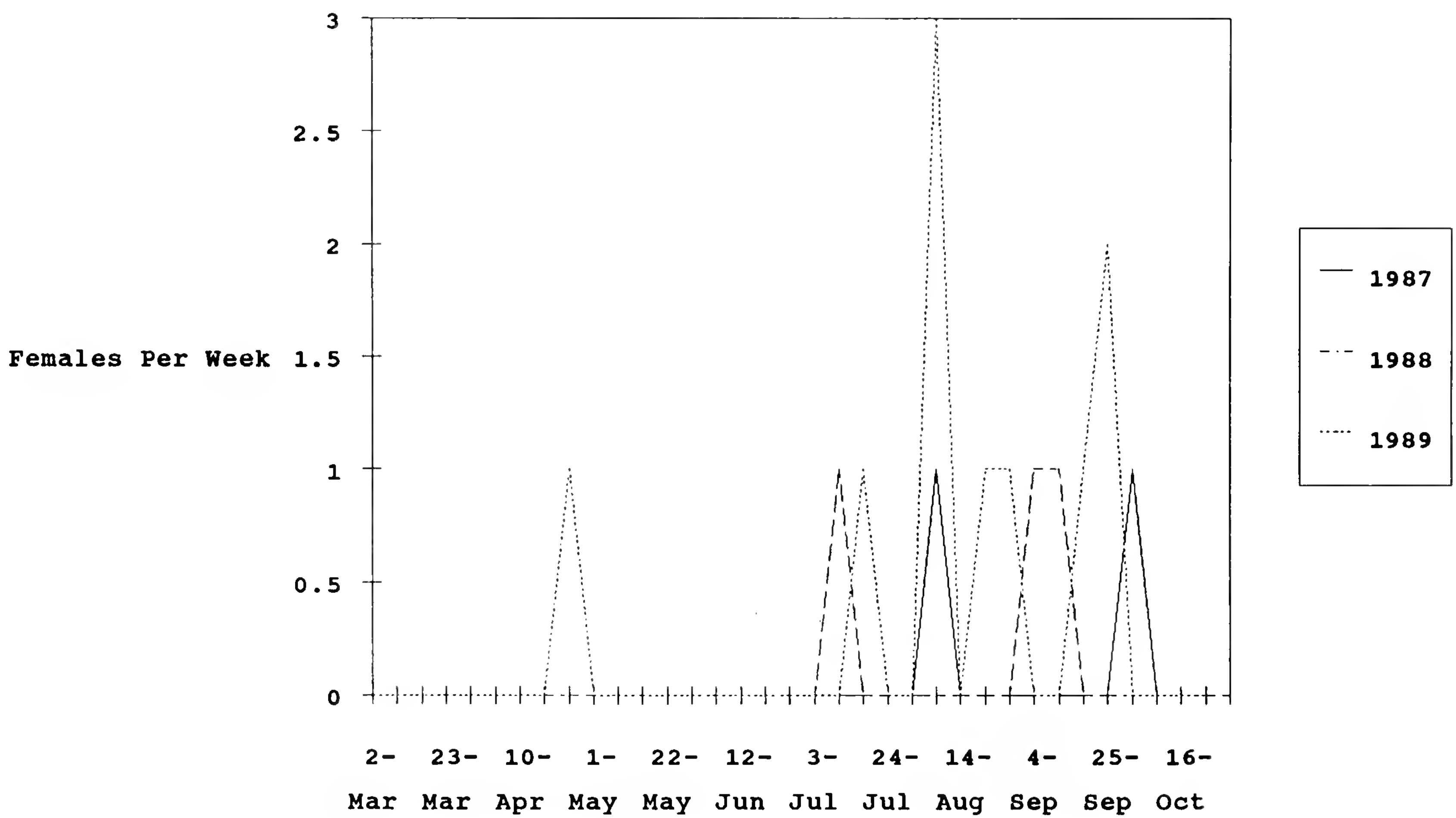
Aedes nigromaculis: Mendota



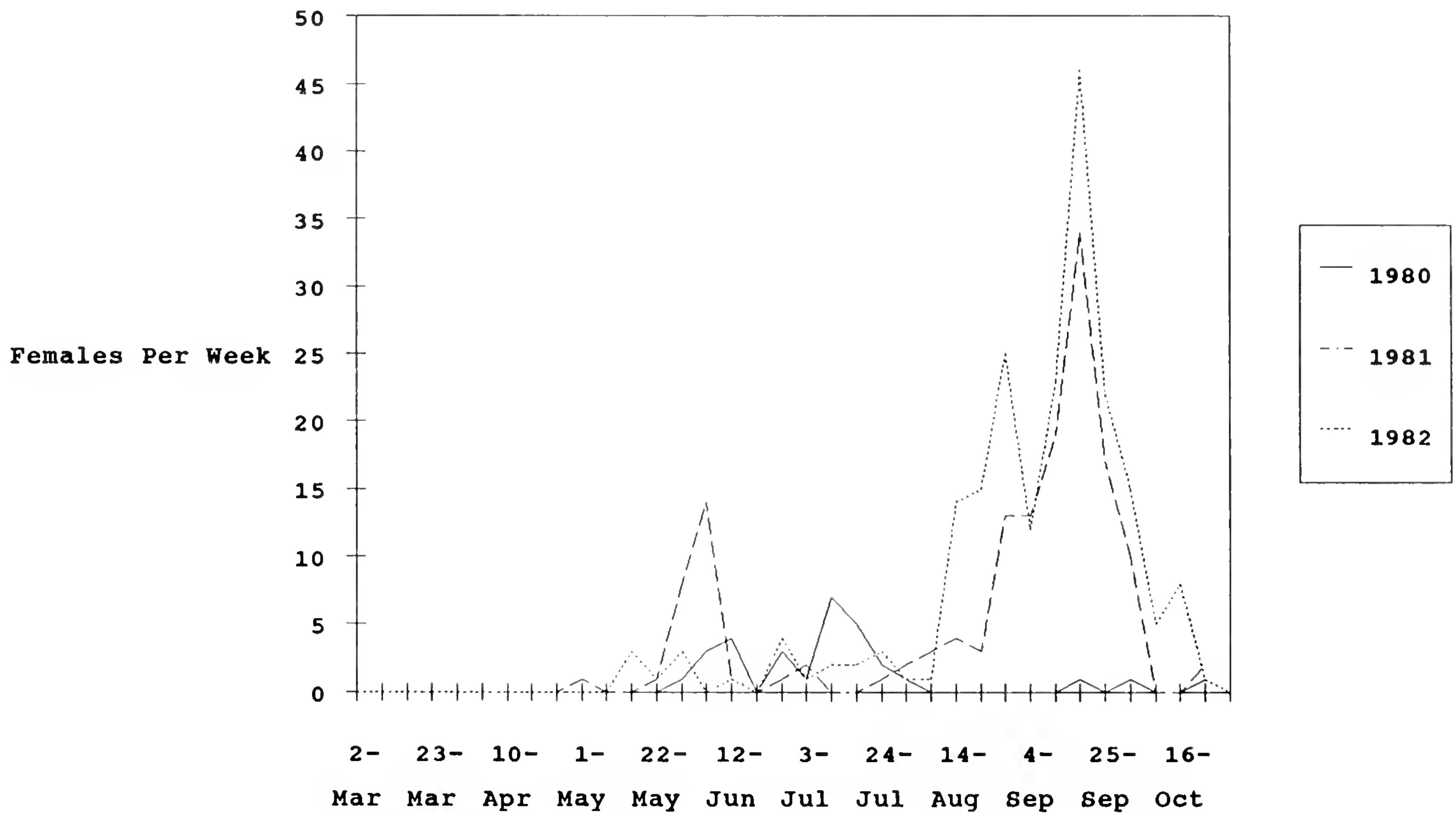
Aedes nigromaculis: Mendota



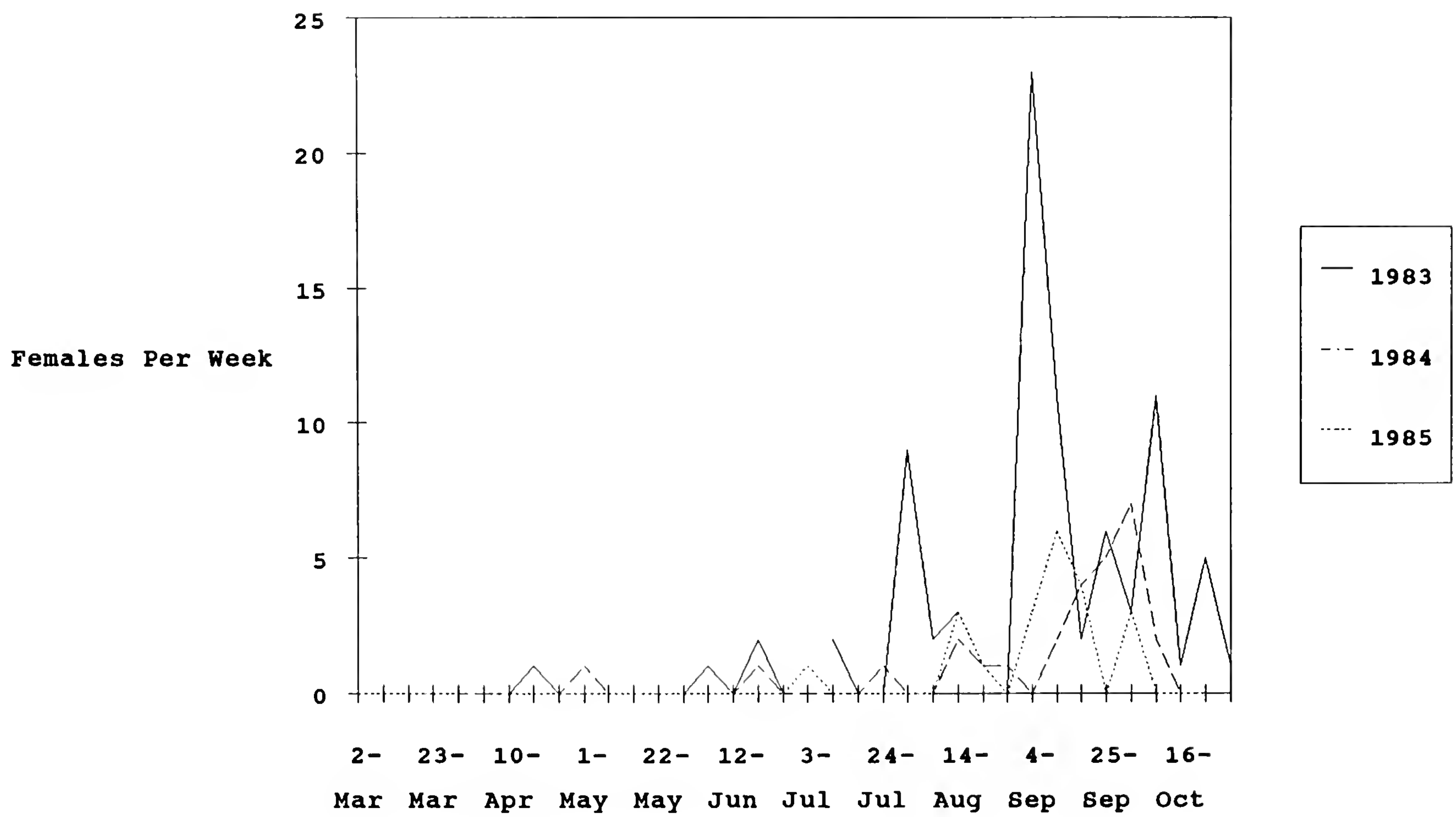
Aedes nigromaculis: Mendota

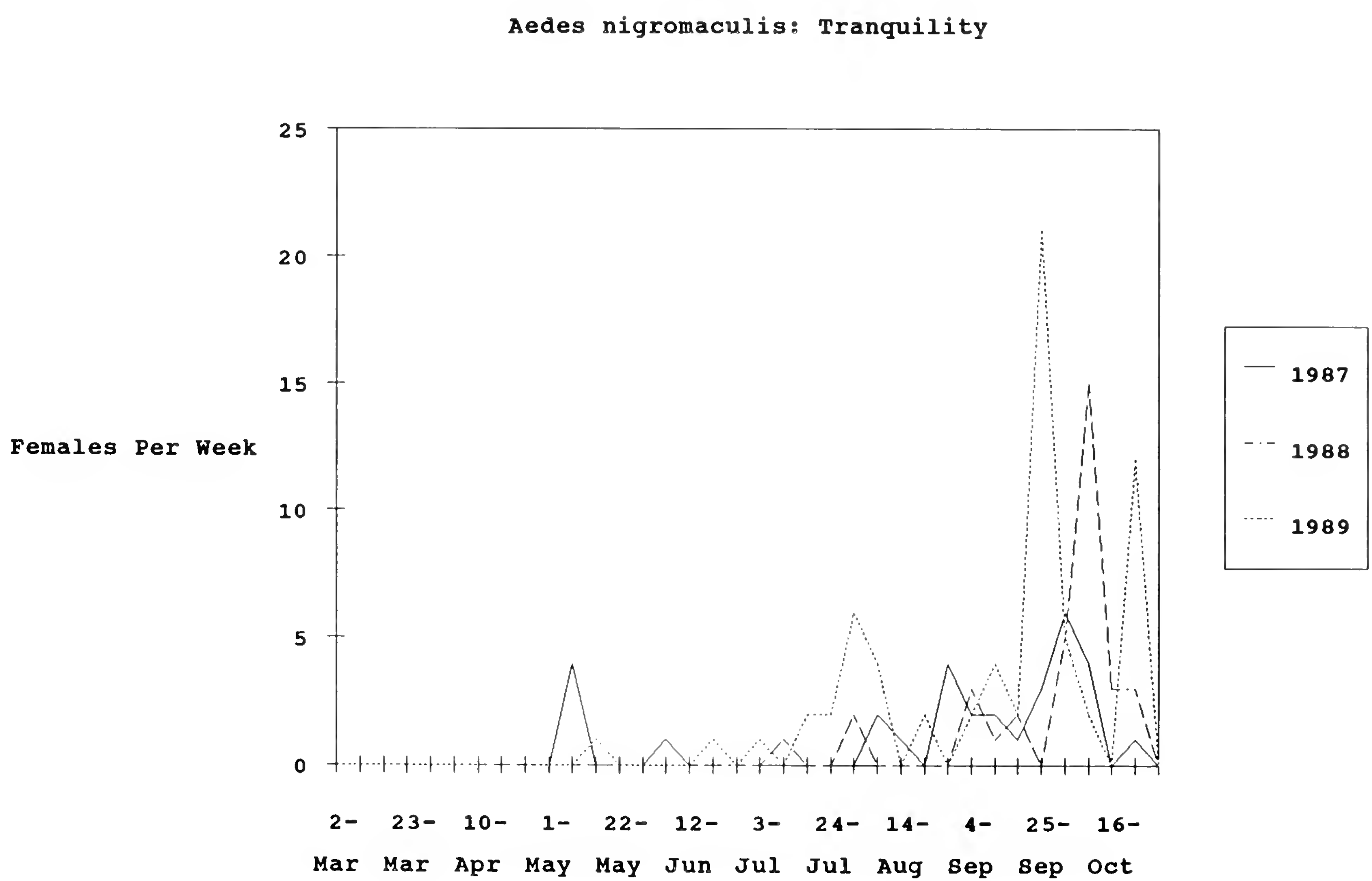


Aedes nigromaculis: Tranquility

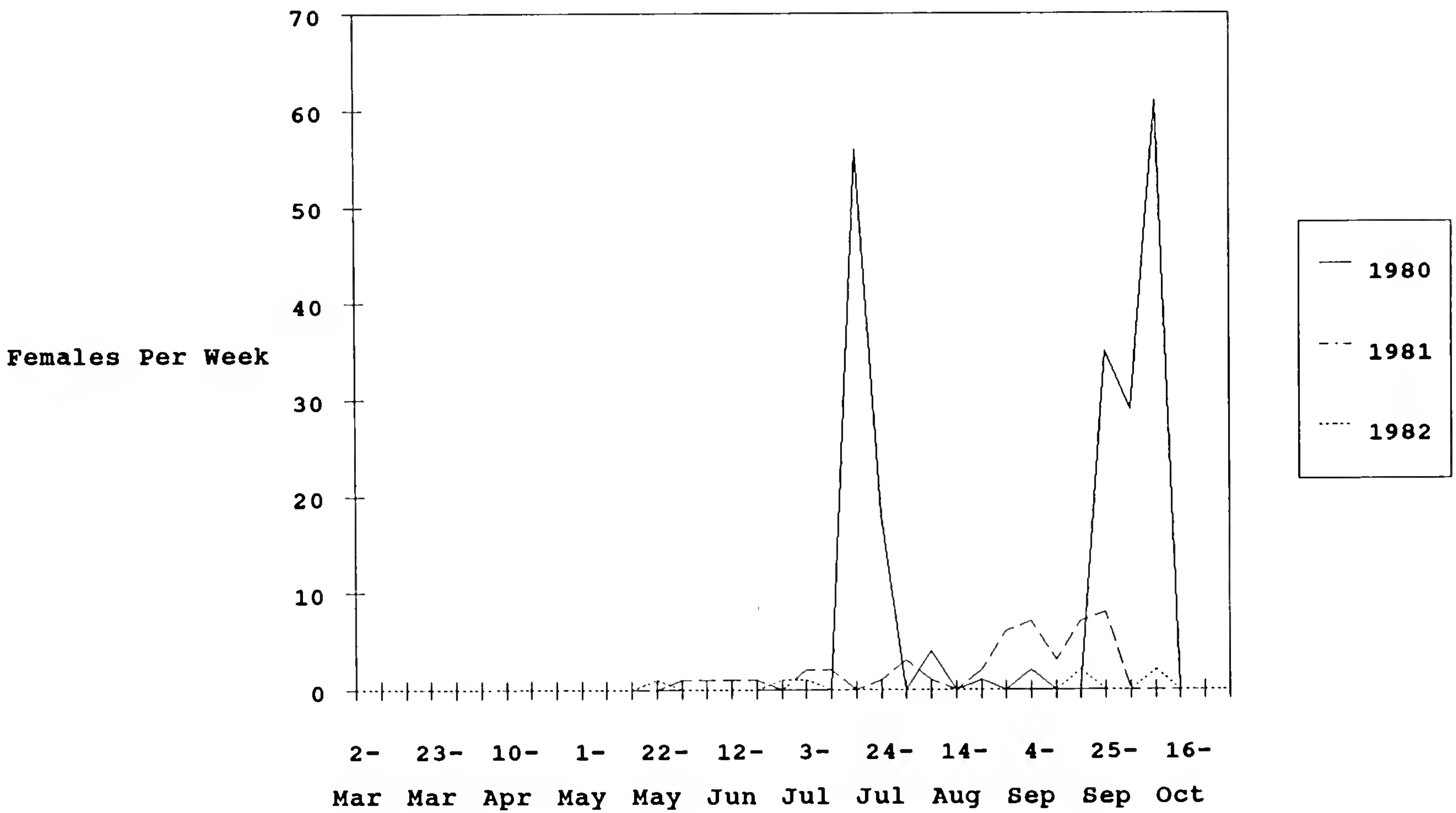


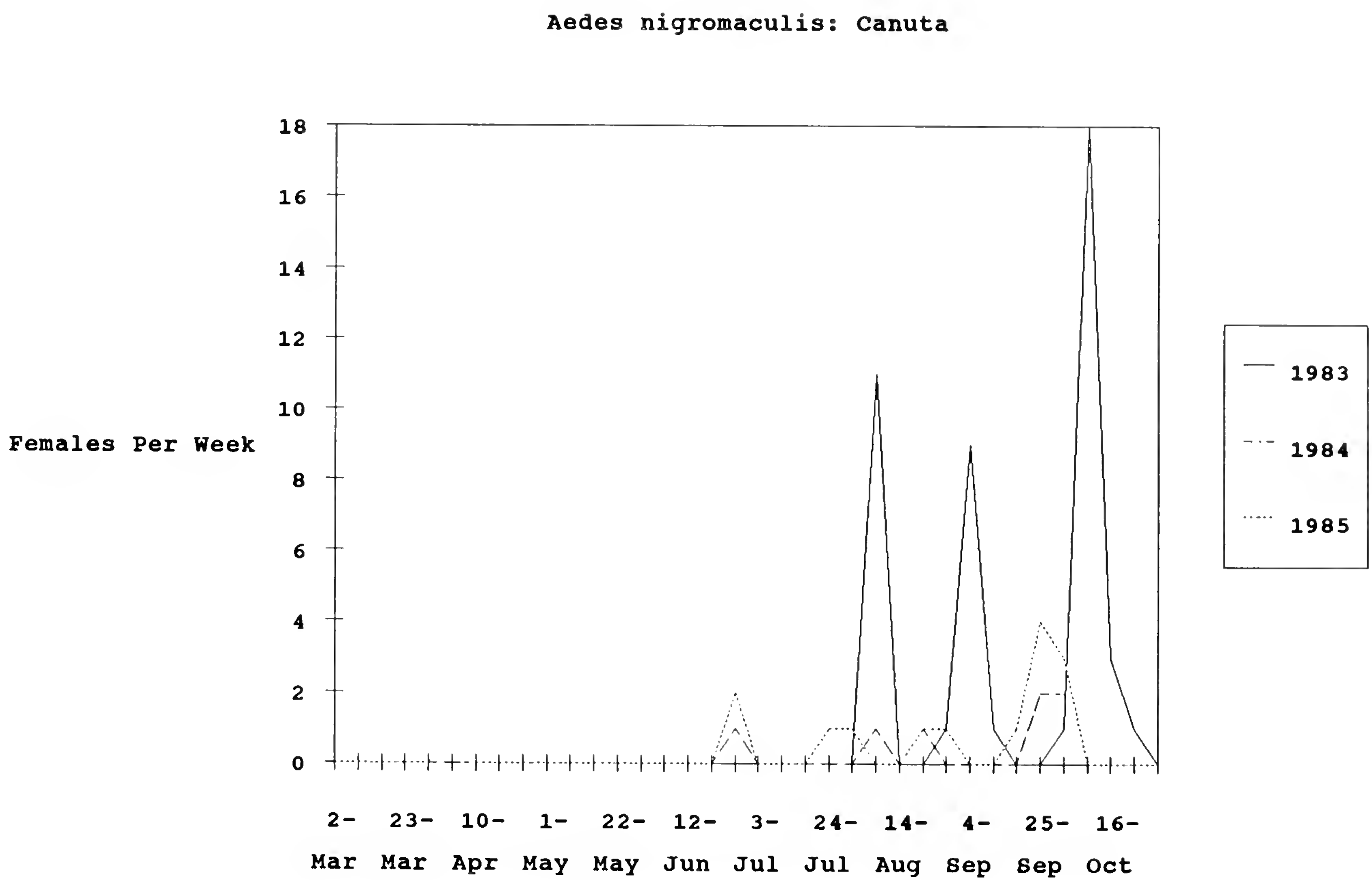
Aedes nigromaculis: Tranquility




Aedes nigromaculis: Tranquility
Females Per Week
25
20
15
10
5
0
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1987
1988
1989

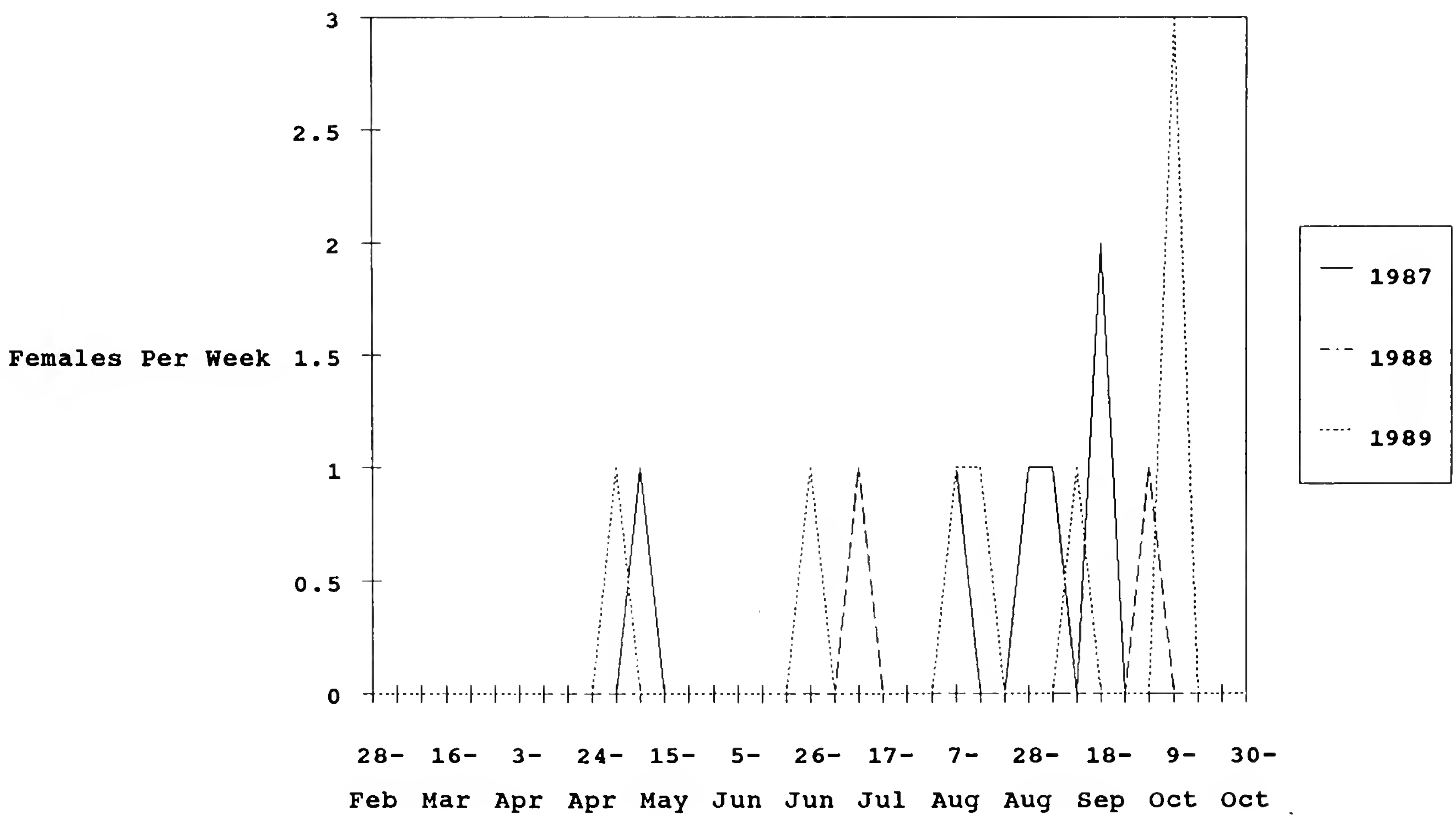
Aedes nigromaculis: Canuta



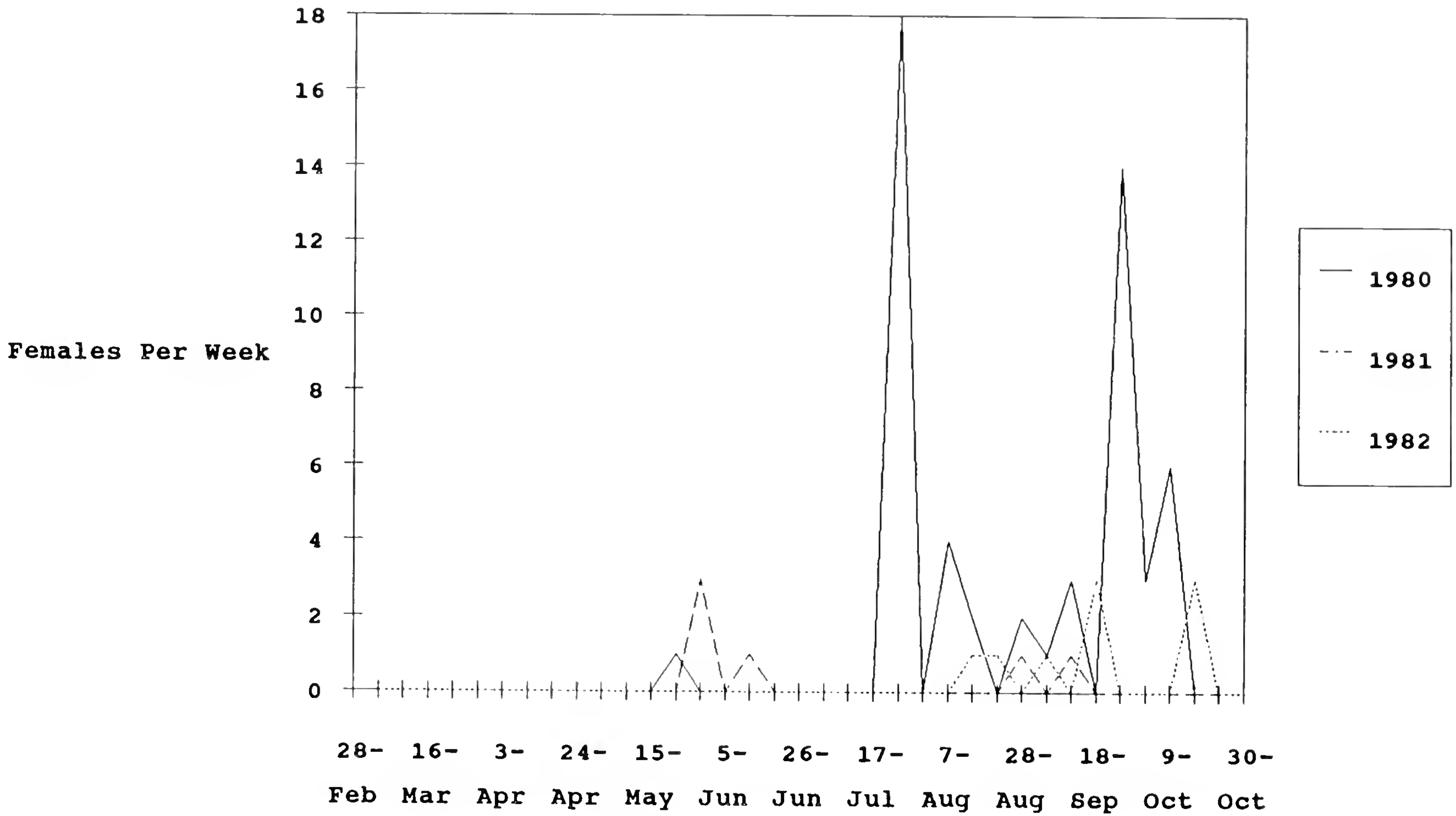


Aedes nigromaculis: Canuta
Females Per Week
0
2
4
6
8
10
12
14
16
18
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1983
1984
1985

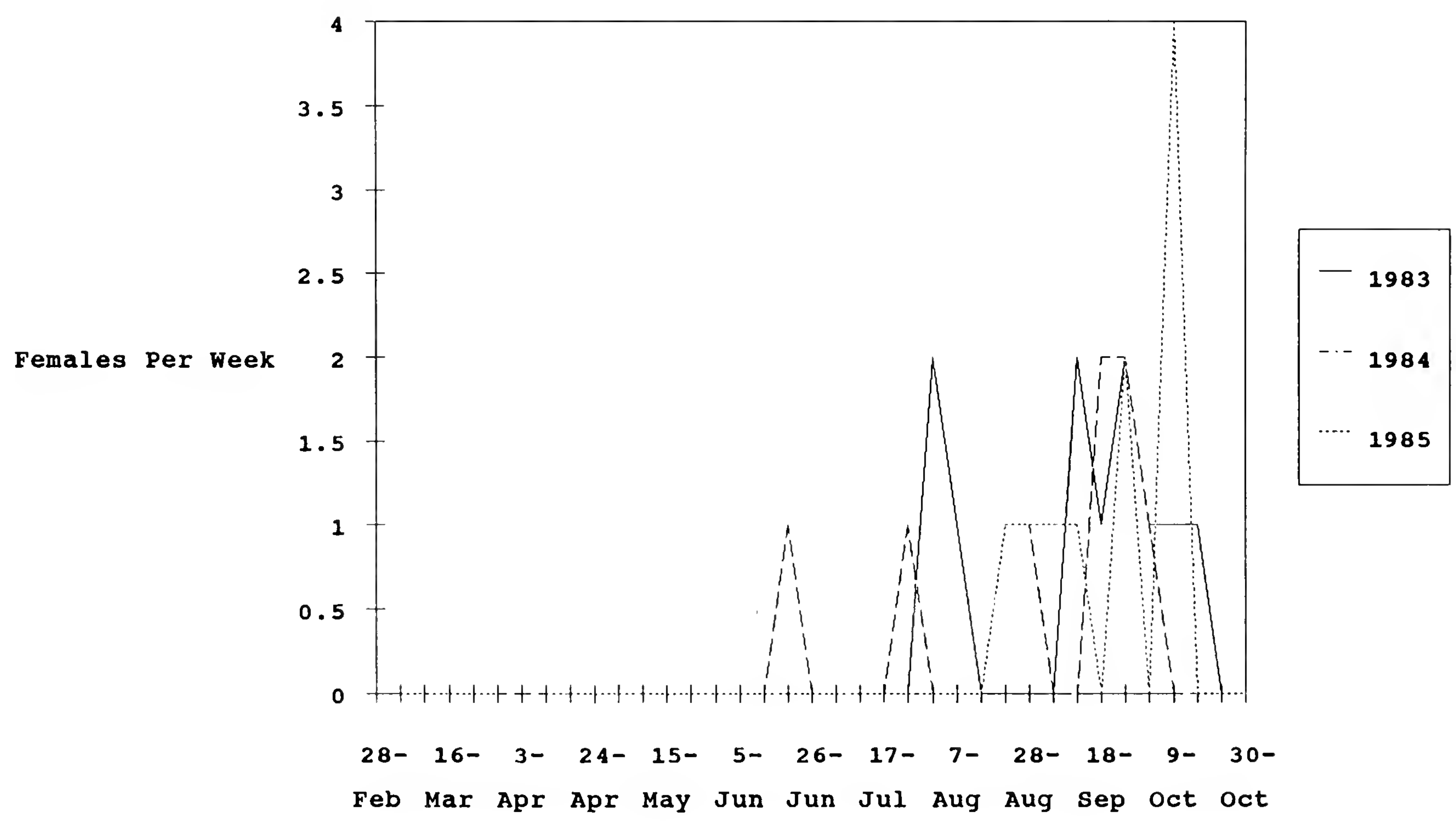
Aedes nigromaculis: Canuta

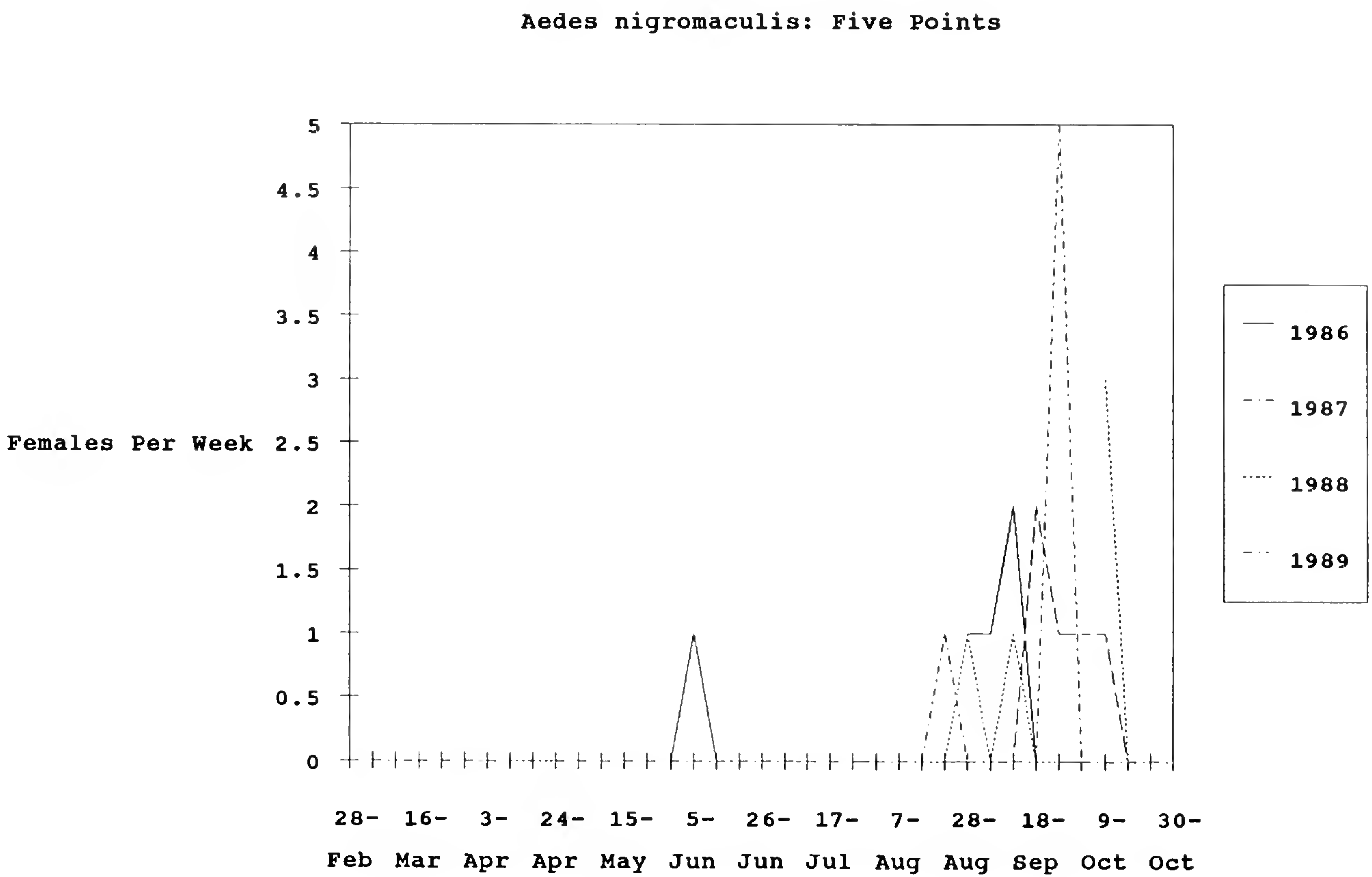


Aedes nigromaculis: Five Points

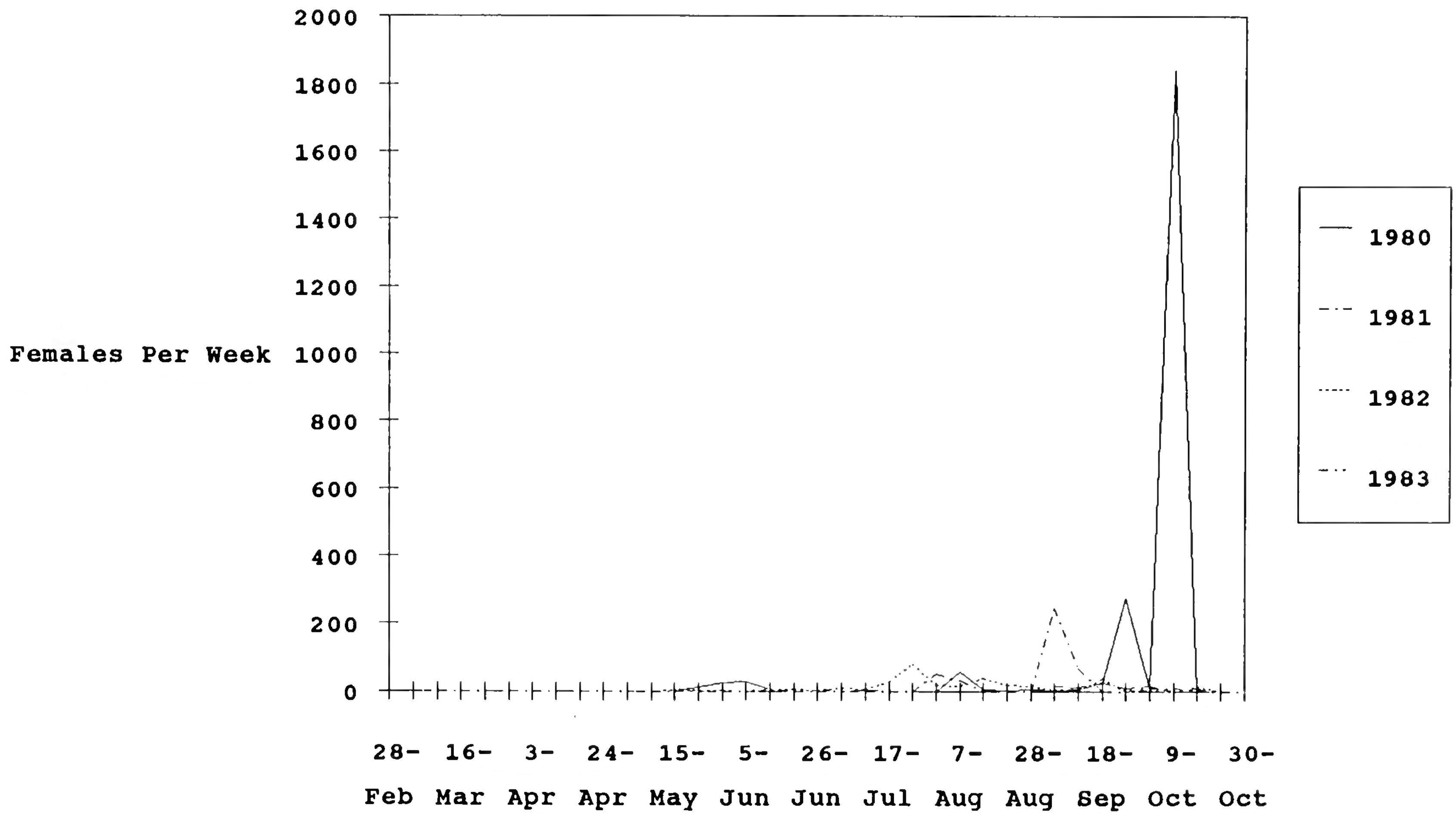


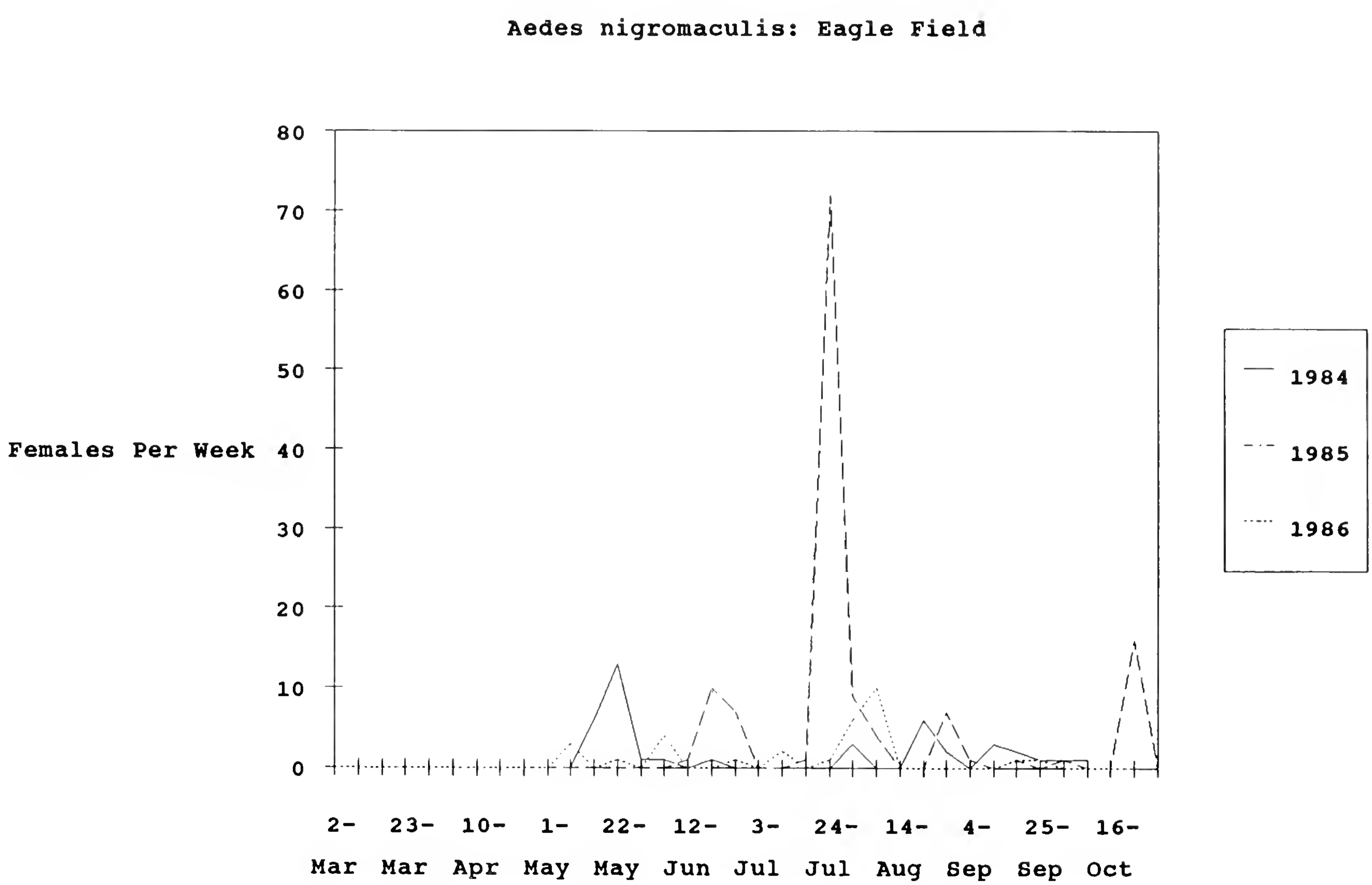
Aedes nigromaculis: Five Points



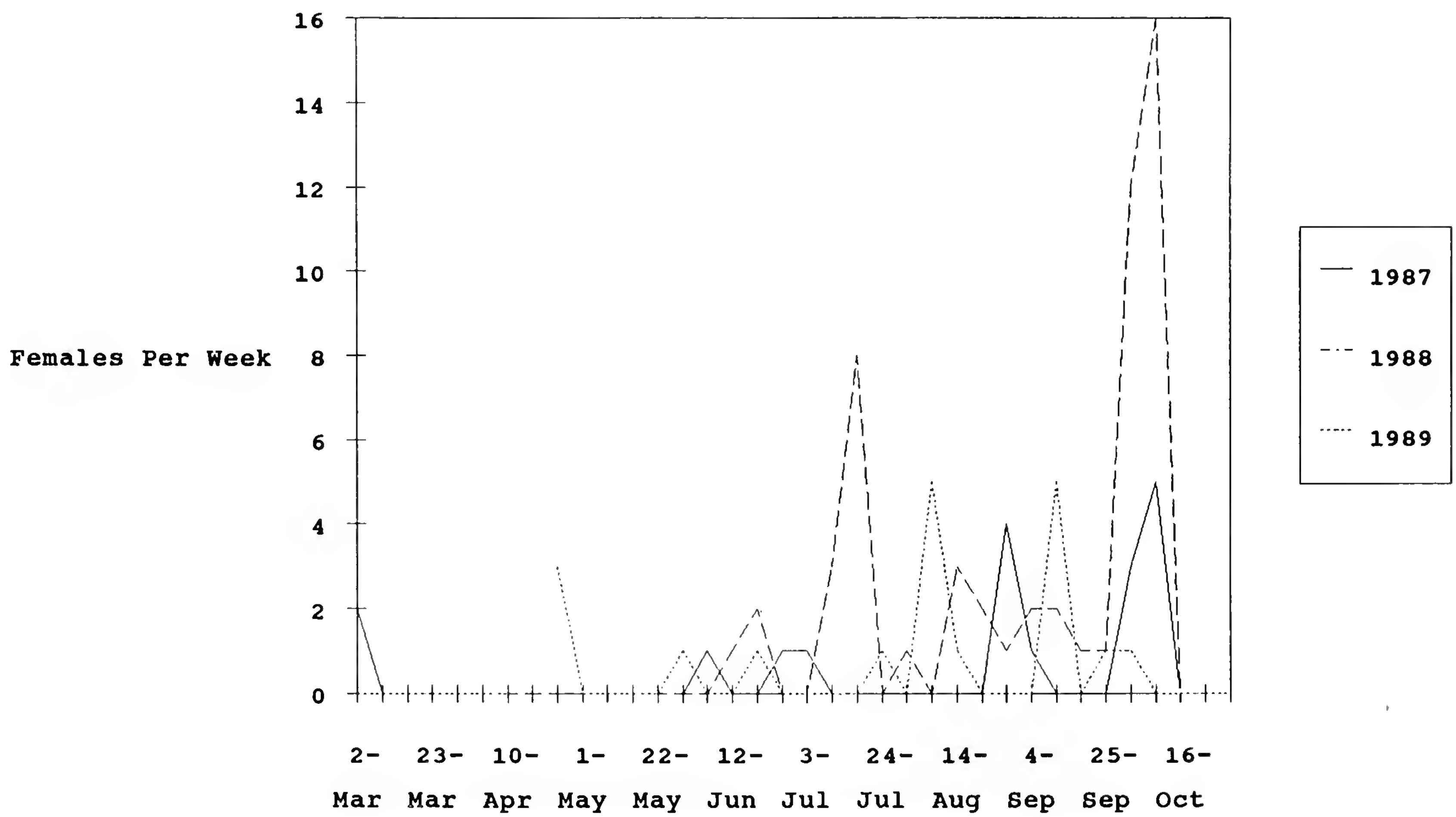

Aedes nigromaculis: Five Points
Females Per Week
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
28- Feb
16- Mar
3- Apr
24- Apr
15- May
5- Jun
26- Jun
17- Jul
7- Aug
28- Aug
18- Sep
9- Oct
30- Oct
1986
1987
1988
1989

Aedes nigromaculis: Eagle Field

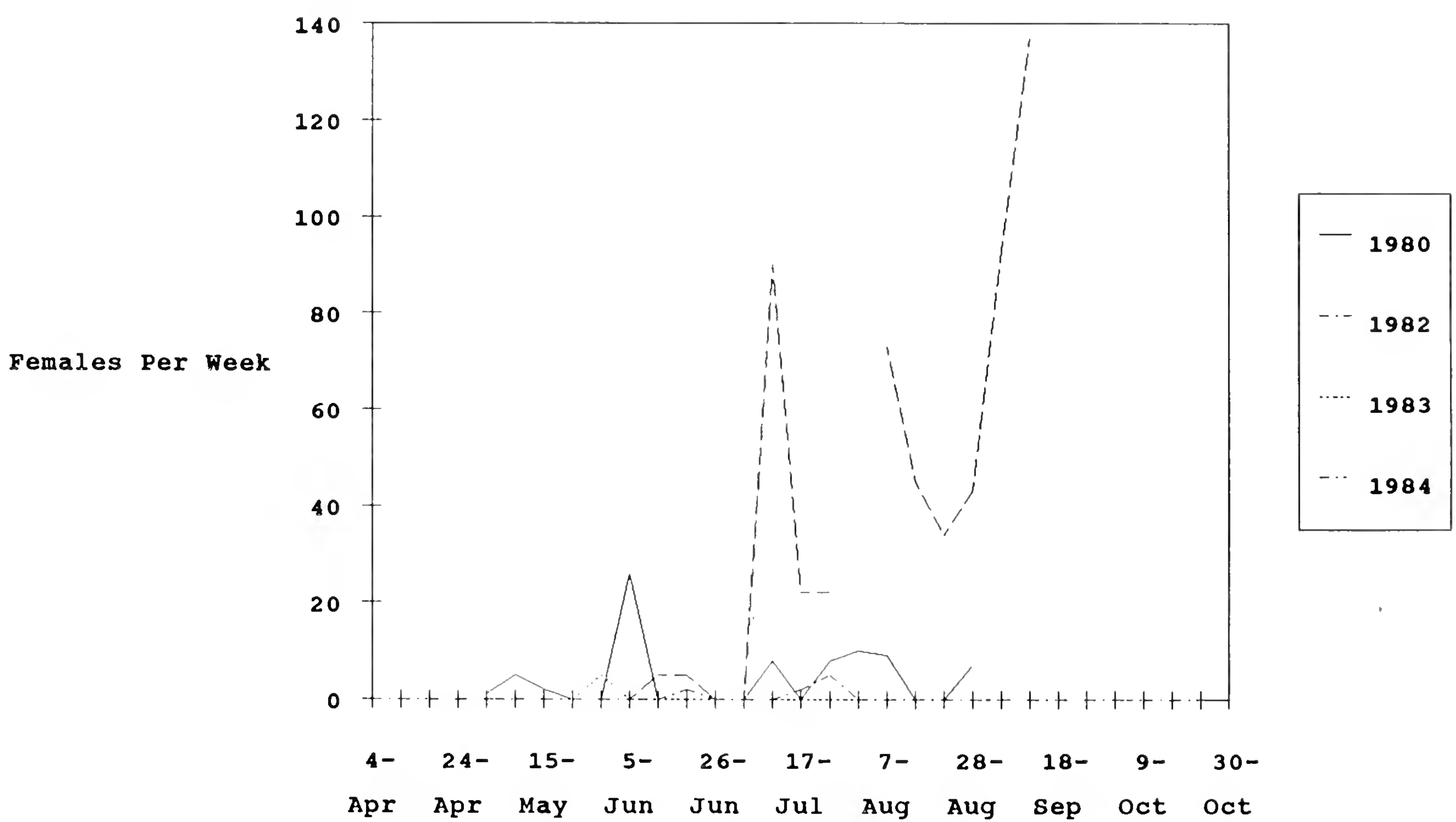



Aedes nigromaculis: Eagle Field
Females Per Week
0
10
20
30
40
50
60
70
80
2- Mar
23- Mar
10- Apr
1- May
22- May
12- Jun
3- Jul
24- Jul
14- Aug
4- Sep
25- Sep
16- Oct
1984
1985
1986

Aedes nigromaculis: Eagle Field



Aedes nigromaculis: Stratford



Aedes nigromaculis: Stratford